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Aeronautical Engineering REVIEW

October, 1956

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Aeronautical Engineering Review

Vol. 15—No. 10 October, 1956

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Cover—A flight of North American F-100C Super Sabres works out at altitude, achieving a formation irresistible to the photographer. The F-100C, which set the world's official speed record of 822.135 m.p.h. on August 20, 1955, has a span of 38 ft., length-overall of 47 ft., range of over 1,000 miles, and carries four M-39 20-mm. cannon. In the 10,000-lb. thrust class, it is a supersonic day fighter that can be fitted with external armament loads for use as a fighter-bomber. It differs from the F-100A in that it contains an in-flight refueling system, provisions to carry extra fuel drop tanks, and bombs.

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I.A.S. News Notes

October 1956

"Whatever our goals in life, we must work hard, study constantly, seek truth and think big and then, truly, those who accept the challenge of flight will find the sky is no limit".....IAS President Edward R. Sharp, before Atlanta Section, September 6, 1956.

THE OPPORTUNITY ENCOMPASSED by the Institute's Flight Test Engineering Fellowship is presented in complete form on Page 20. Though the deadline for applications is March 1, 1957, early inquiries are invited.

CAI-IAS INTERNATIONAL MEETING arrangements, made since first announcement (on the page following) of the Toronto, Canada conference on Nov. 26 and 27 was written, have established identities of authors and titles of 12 papers to be delivered at the four technical sessions. IAS President Edward R. Sharp will find it possible - despite a demanding schedule of speaking engagements - to be present. The printed program, listing complete data, and a dinner reservation form, will reach members soon after this issue of the Review.

A NEW IAS CORPORATE MEMBER is the Standard-Thomson Corporation, of Dayton, Ohio. Edwin E. Aldrin, an IAS Fellow and Benefactor, is Eastern Manager.

UP, UP, UP---As this issue of IAS News Notes goes to press, the world is learning through every available medium that the X-2 has set an altitude record of almost 24 miles - 126,000 feet. The pilot? Captain Iven C. Kincheloe, USAF, a Technical Member of the IAS who is Engineering Experimental Flight Test Pilot at Edwards Air Force Base.

THE SUDDEN DEATH OF CHARLES J. LOWEN, head of the Civil Aeronautics Administration, shocked the Nation on September 5. The 41-year-old Honary Member of the Institute, whose appointment last December brought new vitality into the CAA, was thought to be recovering from an operation in May. Cancer caused his death.

THE THIRD EDITION of prize-winning papers of IAS Student Members has been published by the MINTA MARTIN AERONAUTICAL STUDENT FUND under direction of the Institute. The 185-page volume, "1956 FIRST AWARD PAPERS", contains 11 technical reports (2 more than last year) and authors' figures; it will be mailed to Sections, Student Branches, Faculty Advisers and Corporate Member Representatives. Individual requests for copies will be honored while a limited supply lasts. The publication is another step taken to widen the scope of the Regional Conference program, under the MINTA MARTIN FUND, which also will assist other aspects of the program. In addition, new programs shall be effected, through which the ideals and wishes of MINTA MARTIN will benefit aeronautical students all over the country for years to come.

I.A.S. News Notes (con't.)

NATIONAL MEETINGS CALENDAR

Nov. 26-27 International Meeting, Canadian Aeronautical Institute and the IAS, Royal York Hotel, Toronto, Ontario, Canada.

Dec. 17 Wright Brothers Lecture, U. S. Chamber of Commerce Building Auditorium, Washington, D. C. Sir Arnold Hall, Lecturer.

Jan. 28--Feb. 1 Twenty-Fifth Annual Meeting, Sheraton-Astor Hotel, New York.

Mar. 14-15 Flight Propulsion Meeting (Confidential) Hotel Carter, Cleveland.

Sept. 1-16 Sixth International Aeronautical Conference, Falkstone, England. (See Editorial, this issue.)

* * * * *

SECTION MEETINGS CALENDAR

Oct. 3 - Baltimore Section: Secret Meeting, 2611th Air Reserve Center, 8 p.m. Air Research and Development Command Briefing. Clearance necessary.

Oct. 3 - Philadelphia Section: Dinner Meeting, Penn-Sherwood Hotel, 6:30 p.m. "Problems Associated with Long Range Weapons Systems" by L. B. Cowles.

Oct. 4 - Atlanta Section: Dinner Meeting, Naval Air Station Officers Club, Chamblee, Georgia, 6:30 p.m. "Air Cargo" by Thomas J. Harris.

Oct. 8 - Indianapolis Section: Dinner Meeting, Marott Hotel Marble Room, 6:30 p.m. "The Lockheed Electra Aircraft" by Howard McGlasson.

Oct. 9 - Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "General Considerations for Inlets of Supersonic Speeds" by Oran W. Nicks.

Oct. 9 - San Diego Section: Joint Meeting with ARS, IAS Building, 8 p.m. "Problems of Successful Reentry into the Earth's Atmosphere" by William Dorrance.

Oct. 10 - Niagara Frontier Section: Dinner Meeting, Cornell Aeronautical Laboratory Auditorium, 6 p.m. "Flight Simulators, Past, Present and Future" by Richard C. Dehmel.

Oct. 16 - Cleveland-Akron Section: Dinner Meeting, Manger Hotel, Cleveland, 6 p.m. "Progress to Date on the Earth Satellite" by Herbert Friedman.

Oct. 17 - Columbus Section: Dinner Meeting, Officers Club, Naval Air Station, Port Columbus, 6:30 p.m. "Weather and Aircraft Operations" by R. C. McMaster.

Oct. 18 - Dayton Section: Dinner Meeting, Cordell's Supper Club, Fairborn, 6:30 p.m. "Design Philosophy of the Convair 880 Jet Transport" by A. D. Riedler.

Oct. 18 - Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Plane Sense and Weapon Systems" by Rear Adm. J. S. Russell, USN.

Oct. 19 - New York Section: Dinner Meeting, jointly with ARS, Brass Rail Restaurant, Park Avenue & 40th Street, "USAF Research and Development Program in Rocketry" by Gen. M. C. Demler, USAF.

Oct. 23 - Los Angeles Section: Dinner Meeting, IAS Building, 6 p.m. "Transient Heating Measurement Techniques During High Speed Flight" by Simon de Soto.

IAS News

A Record of People and Events of Interest to Institute Members

Skyways Lead to Canada Nov. 26, 27 For Third Annual CAI-IAS Conference

C. C. Furnas, U.S. Assistant Secretary of Defense, Principal Speaker at Toronto Dinner; Missiles Session and Three Others Slated; American Will Give Turnbull Lecture

AMID INDICATIONS that it will be bigger than last year's event, the 1956 CAI-IAS International Meeting next month is to feature four technical sessions. It will be the third annual joint meeting of the Canadian Aeronautical Institute and the Institute of the Aeronautical Sciences. Prominent roles have been assigned two outstanding Americans; others from the United States will present technical papers.

The Conference will take place on November 26 and 27 at the Royal York Hotel, Toronto, Ont., Canada—about 90 min. from New York. While plans were tentative as this issue of the REVIEW was being prepared, it is expected that any changes will be minor.

IAS Fellow Principal Speaker

Principal speaker at the Conference Dinner will be Clifford C. Furnas, U.S. Assistant Secretary of Defense (Research and Development). Dr. Furnas is a Fellow of the IAS.

The honor of being the first American to deliver the W. Rupert Turnbull Lecture goes to Simon Ramo. Dr. Ramo is Executive Vice-President of The Ramo-Wooldridge Corporation, Los Angeles. (Last year, these two honors went to Canadians.)

J. C. Floyd, Vice-President—Engineering, Avro Aircraft Limited, will be Chairman of the Turnbull Lecture, which was established to perpetuate the memory of one of Canada's outstanding aviation pioneers and benefactors.

Technical sessions will be on Flight Test, Quality Control, Electronics in Aviation, and Missiles, with the latter subject being assigned a climactic position. Each session will consist of three papers. They will be presented by six Americans and six Canadians—an increase of two papers over last year's total.

Registration May Top Last Year

Early interest expressed in the event indicates that a total registration exceeding 500 persons may be anticipated. This would be an increase of about 100 over last year's Conference. In 1955, the United States accounted for about a third of the estimated 400 present. More than 700 attended the Conference Dinner, making it one of the largest banquets ever held in Ottawa.

Dr. Furnas, who is on leave from his post as Chancellor of the University of Buffalo to serve as Assistant Secretary of Defense, succeeded Donald A. Quarles, who became Secretary of the Air Force. Dr. Furnas assumed the post last December.

Directed Cornell Laboratory

From 1946 to 1954, Dr. Furnas was Director of Cornell Aeronautical Laboratory, Inc., Buffalo. He was the Laboratory's first Director and previously had been Director of the same research laboratory when it was operated by the Curtiss-Wright Airplane Division.

Dr. Furnas previously had served the Department of Defense research and development organization in a consultant capacity and had been associated with its predecessor, the Research and Development Board, in various capacities since February, 1948. He also has headed the Technical Advisory Panel on Aeronautics, is a former chairman of the Committee on Guided Missiles, and is a member of the Committee on Aeronautics of the Research and Development Board.

C. C. Furnas, FIAS

During World War II, Dr. Furnas served with groups of the National Defense Research Committee of the Office of Scientific Research and Development which were concerned with physical, chemical, and chemical engineering problems.

Dr. Ramo is an internationally known authority in the fields of electronics systems, guided missiles, and automation. He has predicted that within 10 years a substantial portion of the country's freight could be carried by unmanned or guided missiles.

T. E. Stephenson
1956 President, CAI

Dues Standardized by Council Action

Standardization of dues and abolishment of two grades of membership which will be combined into one new grade has been ordered by the IAS Council on recommendation of the IAS nine-man Membership Committee. The action was taken at the IAS National Summer Meeting at Los Angeles in June.

All changes will be effective as of January 1, 1957. The new dues rates will not pertain to the billing this year. The membership levy for 1957 and ensuing years only is involved.

The two membership grades which are abolished as of January 1, 1957, are Associate Member and Technical Member. Those in the two grades on December 31, 1956, automatically will become Associates and will be so designated thereafter.

After January 1, 1957, the dues for Associates under age 28 will be $7.00 yearly. Dues per annum for Associates over age 28—and for all other grades—will be $15.00.

The Membership Committee is composed of John H. Arms, Charles Froesch, T. F. Hammen, Jr., Jerome Lederer, C. E. Pappas, R. Dixon Speas, Elmer A. Sperry, Jr., F. K. Teichmann, and Charles Tilgner, Jr.

Edward R. Sharp, FIAS, Director of Lewis Flight Propulsion Laboratory, NACA, and President of the Institute of the Aeronautical Sciences, meets with officers of the IAS Student Branch at Parks College of Saint Louis University during Commencement Week. Pictured with Dr. Sharp are Douglas Yando, *left*, Vice-Chairman of the Parks Branch, and Dale Anderson, Chairman. The IAS President delivered the College's midyear Commencement address, speaking on "The Sky Is No Limit." His talk traced recent developments and pointed out opportunities extant for graduates of the aeronautical engineering program in the field of aviation.

Separate Acoustics Unit Is Established at Douglas

Establishment of a "completely separate" Acoustics Section, which it is said was demanded by the growing importance of the sound engineer in the design of commercial aircraft, has been announced by Douglas Aircraft Company, Inc., Santa Monica, Calif.

Matha M. Miller, MIAS, whose developments in the field of acoustics have resulted in numerous technological advancements incorporated in today's air liners, was named Chief of the new section.

In announcing Mr. Miller's appointment, E. F. Burton, Chief Engineer of the Company's Santa Monica Division, declared that the "general technological field of acoustics has become of such importance to aircraft design to the aircraft passenger and to the public that this special phase of engineering is being given increased recognition in our organization."

Research and development in this field, for many years accomplished as a group project within a major engineering section at Douglas, now is given equal status.

Mr. Miller has headed the acoustics program since becoming affiliated with the Santa Monica Division in 1949 and has supervised several major developments.

Under his direction, Douglas is credited with development of the Anacoustic Window, the use of Acoustimat Tape, and the Slip-Stick Partition —all used in one form or another in today's commercial transports, according to Douglas.

The Anacoustic Window introduced an extra inner pane which prevents structure vibrations from entering the airplane in the form of sound. The Acoustimat Tape is used as a sound-damping material on the skin of the airplane, while the Slip-Stick Partition supports the fuselage from the acoustic forces of the propellers.

IAS Opens Competition for Fellowship in Flight Test; Forms Available Now

Do you have a Bachelor's degree in engineering?

Or will you get one before June, 1957?

If so—and you are a citizen of the United States—you qualify as a candidate for the Institute of the Aeronautical Sciences Flight Test Engineering Fellowship.

The Institute invites all eligible to enter the 1957 competition. The successful candidate, or candidates, will join several Air Force and Navy test pilots in a specially designed program providing a solid foundation of advanced technical training in the science of test flight.

Application forms may be obtained by a request in writing, endorsed by a sponsoring reference, addressed to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

The closing date for applications is March 1, 1957.

The Fellowship award has a total value of $4,700. A First-Year Fellow receives $1,500 as stipend and $600 for tuition. A Second-Year Fellow receives $2,000 as stipend and $600 for tuition.

Winning candidates pursue 2 years of graduate study at Princeton, where departmental expenses are covered. Second-year renewal is contingent upon satisfactory performance during the initial year.

The program offered is adjustable. Candidates may be enrolled in an educational institution or employed in the aircraft industry when making application.

Stever Is Given USAF Award for Work as Chief Scientist

H. Guyford Stever, AFIAS, has received the USAF Exceptional Civilian Service Award in recognition of his service to the Air Force as Chief Scientist from February 1, 1955, to July 31, 1956. The presentation was made by Secretary of the Air Force Donald A. Quarles in an afternoon

ceremony in the Secretary's office at the Pentagon.

The citation asserts: "Through his ability as a scientist, his understanding of long range military needs, and his complete devotion to the welfare of the nation, he has assisted in the early solution of highly technical, scientific and unusual management problems vital to national defense. Dr. Stever has devoted himself selflessly in the continuous task of insuring the qualitative superiority of American weapons and has made important contributions to the United States Air Force."

At the time of his appointment, Dr. Stever was Associate Professor of Aeronautical Engineering at Massachusetts Institute of Technology. He has returned to M.I.T. as Associate Dean of the School of Engineering.

Dr. Stever has been succeeded as Chief Scientist by Courtland Davis Perkins, AFIAS, Chairman of the Department of Aeronautical Engineering at Princeton, as reported in the June issue of the REVIEW.

IAS Is Among Sponsors of Air Transport Symposium

Four groups will join forces in presentation of a symposium on Ecology of Air Transport on December 7 in the Institute of the Aeronautical Sciences Building in Los Angeles. The organizations are the IAS, the Aeromedical Engineering Association, the Engineering Extension Division of the University of California, and the Institute of Transportation and Traffic Engineering at U.C.L.A.

Chairman will be John R. Poppen, M.D., AFIAS. Other conference leaders will be Heinz Haber and Harry Mathewson of the Institute at U.C.L.A. and Harry Morehouse of the University's Physical Education Department.

The word "ecology" in the symposium title is used in the dictionary sense of the mutual relations between organisms and their environment. Los Angeles planners have designed the study to present a view of conditions in the foreseeable future and to exploit the areas in which cooperative effort is necessary.

Tentative program plans include discussions of local, national, global, and spatial air policy, air facility planning, characteristics of tomorrow's air carrier, and commercial and military traffic control systems. A panel is planned for the presentation of viewpoints of problems of forthcoming air transport.

Other sessions will deal with passenger attitudes and the psychology of the air passenger, physiology of global flights, and other facts of air transport.

Two IAS Members Reappointed Guggenheim Fellows

Two IAS members have been notified by the Daniel and Florence Guggenheim Foundation of reappointments as Guggenheim Fellows.

Meredith C. Gourdine, TMIAS, of Brooklyn, will continue studies at the Guggenheim Jet Propulsion Center at California Institute of Technology. The Center and a similar one at Princeton were established in 1948 to train promising graduate students for leadership in the rocket and jet propulsion fields.

Michael I. Jarymowycz, STMIAS, Bronx, will resume his studies at the Daniel and Florence Guggenheim Institute of Flight Structures at Columbia University. This school was founded in 1954 as a unit of the School of Engineering under sponsorship of the Foundation.

Fellowships provide stipends ranging from $1,200 to $2,000 annually, plus tuition.

IAS Member Is Officer in New Aerophysics Firm

Carl E. Hall, MIAS, and Howard M. Webb have formed American Aerophysics Corporation with headquarters in Los Angeles.

The new firm will engage in aeronautical research and development with emphasis on aerodynamic, structural, and mechanical problems of missiles.

Mr. Webb is President and Mr. Hall Vice-President. Both are former associate project engineers with the Aerophysics Development Corporation, Santa Monica, Calif.

Necrology

Earl V. Farrar

Earl V. Farrar, Chief Engineer of the Wright Aeronautical Division of the Curtiss-Wright Corporation, Wood-Ridge, N.J., died suddenly of a heart attack in his home, 216 Gardner Road, Ridgewood, N.J., on August 11.

Mr. Farrar had been an Associate Fellow, IAS, since October 30, 1953; his membership dated from July 21, 1950. He was coauthor, with R. E. Johnson, of an IAS paper "Do We Need Turbo-Props?" presented at the 1950 Cleveland Flight Propulsion Meeting.

Born in Calvert, Kan., in 1903, Mr. Farrar received a Bachelor of Science degree in Mechanical Engineering from Kansas State College in 1926, a Master of Science degree from Purdue University in 1929, and a Mechanical Engineering degree from Kansas State in 1931. While at college, he was admitted to Sigma Tau, honorary engineering society, and during his graduate studies was an Instructor in Descriptive Geometry and Engineering Drawing. Later, during his professional career, he gave courses in Engine Dynamics at New York University.

Mr. Farrar started his career with Wright Aeronautical Corporation, Paterson, N.J., in 1929 as a layout draftsman and progressed through many departments. He was named Chief Engineer last year, having been instrumental in design and development of a long line of Wright military and commercial engines.

Mr. Farrar was a member of the Society of Automotive Engineers, in addition to the Institute. He participated in professional activities as an active member of the Engine Technical Committee of the Aircraft Industries Association. He also had served as a representative of his Division to the Gear Manufacturers Association, as a member of the Automotive Council for War Production, and as a member of the NACA Turbine Subcommittee. He also served as a member of the U.S. Naval Technical Mission in Europe in 1945 and was industry representative on a special U.S. Air Force survey team in France and England in 1952.

Survivors include his wife, two children, his father, and three brothers.

Carl Hinshaw

Representative Carl Hinshaw, MIAS, member of Congress since 1938 and one of its leading authorities on aviation, died August 5 at Bethesda Naval Hospital, Washington, D.C. Sixty-two years old, he became affiliated with the IAS on June 28, 1945. His death was attributed to pneumonia complicated by a heart condition.

Born in Chicago, Mr. Hinshaw included among his duties on the Committee on Interstate and Foreign Commerce the investigation of plane crashes; he had been active in this effort since 1940 and most recently was investigating the June 30 mid-air collision of two air liners over the Grand Canyon.

From 1929 to 1938, he was a member of the real estate insurance brokerage firm of Morse-Hinshaw Company, Pasadena, Calif., and in the latter year was elected to the 76th Congress. Exactly 10 years later, he received the Citation of Honor from the Air Force

Association and, in 1953, the Wright Brothers Memorial Trophy of the National Aeronautic Association.

Vitally interested in the development of atomic energy for peaceful uses, he was in the vanguard of those seeking easing of immigration requirements for alien scientists. He also was a member of the Joint Congressional Committee on Atomic Energy.

Prior to enlistment in the Army in 1917, Mr. Hinshaw had received a civil engineering degree at Princeton University. In 1919, he resigned from the Army Corps of Engineers with the rank of Captain.

Surviving are his widow, two sons, and his mother.

Eugene Barton Hoffman

Eugene Barton Hoffman, TMIAS, a member of the Aerodynamics Section of Engineering in the Los Angeles Plant of North American Aviation, Inc., was among 128 persons who lost their lives in the mid-air collision on June 30 of two commercial air liners over the Grand Canyon.

Mr. Hoffman, 26 years old was en route to Pittsburgh on company business. His untimely death followed by only a few days his receipt of a Master's degree in aeronautical engineering from the University of Southern California. He had planned to continue his post-graduate studies in the field.

Mr. Hoffman became affiliated with the Institute as a Student Member in November, 1949, while attending the University of Pittsburgh. An aeronautical and mechanical engineering major, he was graduated as an outstanding senior in the aeronautical engineering department in June, 1951, and in the same month joined North American as an engineer draftsman.

He is survived by his parents, a brother, and a sister, all of Pittsburgh.

Captain Paul J. Burr, USN, AFIAS, has been transferred from Aircraft Material Officer on the Staff of the Air Force Commander, Pacific Fleet, to Executive Director of the Field Activities Group, Bureau of Aeronautics.

NEWS OF MEMBERS

▸ **Samuel B. Batdorf** (AF) has joined Lockheed Missile Systems Division's research branch as Assistant Director and Head of the Electronics Division. Dr. Batdorf will direct activities in electronics research, electronics development, flight-test electronics, and advanced telemetering development. He is former Director of Development, Engineering Headquarters Staff, Westinghouse Electric Corporation.

Hermann H. Kurzweg, AFIAS, has been named by the Navy Department to the newly established post of Associate Technical Director for Aeroballistic Research at the U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md. Dr. Kurzweg has been with the Laboratory since 1946 and has served as Chief of its Aeroballistic Research Department since 1952. In 1951, he received the Navy's Meritorious Civilian Service Award for outstanding work.

▸ **William M. Duke** (AF), former Vice-President of the Cornell Aeronautical Research Laboratory, has been named Program Director for the Titian ICBM Program at The Ramo-Wooldridge Corporation, Los Angeles.

▸ **George Gerard** (AF), Assistant Director, Research Division, New York University College of Engineering, has been named also Research Professor of Aeronautical Engineering.

▸ **W. C. Heath** (AF) has been named to the newly created post of Projects Manager in Solar Aircraft Company's San Diego plant to undertake major projects and be responsible for coordinating activities pertaining to them among various company divisions. He is a former Chairman of the San Diego Section.

▸ **J. S. McDonnell** (F), President of McDonnell Aircraft Corporation, recently was honored by his Class (1921) at Princeton in a citation for distinguished service to the United States. The award, lauding Mr. McDonnell as an "outstanding engineer and good citizen," stressed contributions of his firm's "trial blazing" in development of military aircraft for the nation's defense and praised him as "celebrated for his efficiency in preventing waste; for his success in winning the cooperation and loyalty of co-workers. . . . He has made an outstanding contribution to the whole defense program." The citation also took note of the McDonnell Foundation peace fund and of the work Mr. McDonnell has done in education and community service.

▸ **Ross A. McFarland, M.D.** (M), of the Harvard School of Public Health has been honored with an award inscribed: "An appreciation to Ross A. McFarland, in recognition of outstanding contributions for the im-

Jagannath P. Chawla, M, has instituted an award of 500 rupees for the year 1956 to be given for the best paper on any aspect of aeronautics either read before the Aeronautical Society of India or written for publication in the Journal of the Society during the year. The award is open to all members of the Society and all citizens of the Republic of India. It will be administered and presented by the Aeronautical Society of India.

provement of knowledge of military medicine of importance to national defense." The award was presented recently by Gen. S. B. Hays, Surgeon General of the Army, after Dr. McFarland gave the second annual James Stevens Simmons Memorial Lecture on "The Role of Human Factors in Accidental Trauma" at the Walter Reed Army Medical Center.

▸ **Angelo Miele** (M), an Associate Professor of Aeronautical Engineering at Purdue University, has been appointed an Engineering Consultant, Missiles Division, Douglas Aircraft Company, Inc., Santa Monica, Calif.

▸ **Edward M. Powers, Major Gen., USAF (Ret.)** (F), has been elected to the Board of Directors of Flight Refueling, Inc., Baltimore. He is a member of the consultant firm, Powers and Mulligan, Montclair, N. J., and formerly was Vice-President of the Curtiss-Wright Corporation.

▸ **Edwin L. Resler, Jr.** (M), has been appointed an Associate Professor of Aeronautical Engineering by Cornell University, where he will be in charge of the Gasdynamics Laboratory of the Graduate School of Aeronautical Engineering. Since 1952, he has been an Associate Research Professor in the University of Maryland Institute for Fluid Dynamics and Applied Mathematics.

▸ **Alfred F. Stott** (AF) has been elected Vice-President of The Aeronautical University, Inc., Chicago, by action of the Board of Directors. A former Chairman and Secretary of the Chicago Section, IAS, Mr. Stott will continue as the University's Dean of Engineering. He recently observed his twenty-second year with A.U.

▸ **Harry F. Vickers** (M) has been designated recipient of the second highest honor of the American Society of Mechanical Engineers—the ASME Medal for "distinguished service in engineering and science." Mr. Vickers, President of Sperry Rand Corporation, will be cited in particular for "pioneering in industrial oil hydraulics and for notable accomplishments in business leadership."

▸ **Theodore von Kármán** (HF), chairman of the Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization, has received an Honorary Doctorate from the Technological Institute of Delft.

▸ **Frank L. Wattendorf** (F), Director, Secretariat, Advisory Group for Aeronautical Research & Development, NATO, has been elected a Fellow of the Royal Aeronautical Society.

M. J. Thompson, AFIAS, Professor and Chairman of the Aeronautical Engineering Department of The University of Texas, and Associate Director of its Defense Research Laboratory since 1945, has been elected a Fellow in the American Society of Mechanical Engineers. Dr. Thompson has directed technical development of two supersonic wind tunnels, has contributed to development and teaching of courses at a number of engineering colleges, and has served as consultant on numerous aeronautical projects.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Norman J. Ball (M) has been promoted to Assistant Head, Flight Research Department, in the recently formed Full-Scale Division of Cornell Aeronautical Laboratory, Inc. He is former head of CAL's Variable Stability Airplane Project.

K. M. Barnes (TM), Chief Flight and Safety Engineer for the Hardman Tool and Engineering Company, has been named to head a new flight safety accessory division which will place emphasis on research and project development activities. All facilities of the firm will be at the disposal of the new division.

Murray Berkow (M) has been appointed Assistant Sales Manager in Charge of Weapons Systems by Republic Aviation Corporation, to be responsible for the operations of field service and the weapons systems requirements division.

King D. Bird (M) has been appointed Assistant Head of the Cornell Aeronautical Laboratory Wind Tunnel Department in Buffalo. He was employed at the WADC Aircraft Laboratory and at the Applied Physics Laboratory of John Hopkins University before joining CAL in 1951.

Howard S. Coleman (M) has been elected Vice-President in Charge of Research and Engineering, Bausch & Lomb Optical Co., Rochester, N.Y., becoming one of the youngest men (39) in the United States to hold such a position with a major firm.

Herbert De Cenzo (M) has been named Chief Engineer to head a new coupling division established by On Mark Engineering Company, Glendale, Calif. During a period of Navy service, Mr. De Cenzo was instrumental in the filing of 12 patents, six of which were fully credited to him.

Jean H. DuBuque (M) has resigned his post as Executive Director and Secretary of the National Business Aircraft Association, Inc., with headquarters in Washington, D.C.

Frank W. Godsey, Jr. (M), has resigned as Manager of the Baltimore divisions of Westinghouse Corporation.

Raymond F. Halen (M), Sales and Liaison Engineer for the Eastern Seaboard from 1948 to 1951 for Hydro-Aire, Inc., has rejoined the firm in the same capacity. Mr. Halen, who began his aviation career with Republic Aviation Corporation, will maintain headquarters in the New York City area.

John R. Harkness (M) has resigned as General Manager of Kearfott Company, Inc., a subsidiary of General Precision Equipment Corporation.

Seymour W. Herwald (M) has been appointed Manager of the Baltimore Air Arm Division, Westinghouse Electric Corporation, succeeding B. M. Brown, who has been named Manager of all Baltimore divisions. Author of many technical articles, Dr. Herwald joined Westinghouse in 1939.

Richard K. Koegler (M) has been promoted to Administrative Engineer in the Vehicle Dynamics Department of the recently formed Full-Scale Division of Cornell Aeronautical Laboratory, Inc. He formerly headed the Aeronautical Engineering Branch, Flight Research Department.

Johann Ludloff (M) has been promoted from Associate Professor to Professor of Aeronautical Engineering in the New York University College of Engineering. In addition to teaching, Dr. Ludloff directs research on the aerodynamics of shock waves.

N. V. Petrou (M) has been appointed Engineering Manager of the Baltimore Air Arm Division, Westinghouse Electric Corporation, succeeding Seymour W. Herwald (M), who has been named Manager of the unit. Mr. Petrou joined Westinghouse in 1941.

Marvin B. Ruffin (AM), former Vice-President Customer Relations, has been named Vice-President General Manager of Summers Gyroscope Company, Santa Monica, Calif.

Roman M. Spangler, Jr. (M), has become affiliated with the Lycoming Division of AVCO Manufacturing Corporation as Powerplant Installation Engineer.

Ellis R. Spaulding (M) has been promoted to fill the post of Administration Engineer, Flight Research Department, in the recently formed Full-Scale Division of Cornell Aeronautical Laboratory, Inc. He has been in charge of the Mechanical and Electrical Engineering Branch, Flight Research Department.

(*Continued on page 82*)

Editorial

Here We Go Again!

It is sometimes amazing how quickly the 2-year intervals between our international conferences slip by. A few weeks ago (at the Third Turbine Transport Meeting in San Diego), it seemed incredible that over a year had passed since we had entertained the delegates of The Royal Aeronautical Society at Coronado, and, as this is being written (at the Sixth General Assembly of AGARD in Brussels), it seems equally impossible that our meeting with the British Society comes up in just about a year's time.

The Brussels meeting provided an excellent opportunity for preliminary planning talks between the two groups. Dr. Ballantyne and his staff conferred with the Director and the Secretary of the IAS on questions of locale, activities, and programs. Each time we do it, the planning is easier. The requirements of our two groups are more readily appreciated. We understand each other better. With five international conferences already "over the dam," we have laid a solid foundation for the future.

Although the final details of the technical programs have not yet been settled (specific papers by particular authors are now being solicited on both sides), the general topical outline of the meetings has been established. As usual, security problems have been bothersome (and are not yet entirely resolved), because all sessions must be unclassified, but it is certain that wide areas of common interest exist that may be explored to our mutual advantage.

On time and place of the Sixth Conference, we can be more specific. As is customary for our meeting in the United Kingdom, the program is geared to the SBAC's Farnborough Show. This always falls in early September. For 1957 it comes in the first week of the month. With the RAeS-IAS meetings scheduled immediately afterward, the bracketing dates for the two series of events are September 1–16. Note them

down on your calendars. Bearing in mind the heavy travel demands of that time of year to and from Europe, we suggest that you make your hotel and transportation reservations early! (The Institute has made an arrangement with a travel bureau to handle all our reservation requirements. Full particulars can be obtained by writing to R. R. Dexter, Secretary, IAS.)

In line with the British concept that technical meetings can be made more homogeneous and more profitable if held in a spot that offers fewer distractions than does London, the seaside resort of Folkstone has been selected for 1957. We understand that arrangements similar to those at Brighton (1953) have been made for the meeting places and for the accommodation of the delegates (although we doubt that Folkstone has anything to match the famous Pavillion and riding stables of Brighton!). Again, the full particulars will be made available to our members in due course via the Secretariats of both Societies.

As we now understand it, the technical sessions at Folkstone will wind up the Conference program. Attendance at the Farnborough Show and a series of visits to aircraft and engine manufacturing plants and to certain government installations will precede these meetings. During this phase of the operation, all delegates will be based in London.

Enthusiasm for the joint British-American conferences remains high on both sides of the Atlantic. The advantages to both groups have long since been recognized and are now accepted without question. Considerable pressure is developing to broaden the base of our conferences by expanding participation beyond strictly Anglo-American boundaries. The question of official participation by the Canadian Aeronautical Institute is under discussion by both Councils. The CAI is so closely tied to both the RAeS and the IAS that its eventual participation on an equal basis with the older Societies would seem to be a natural development. How far we can go beyond that point is an open question.

The desirability of international conferences in aeronautics is now well established, but too many of them may well become burdensome and end up by defeating their basic purposes. The attendance here at AGARD's Sixth General Assembly is ample evidence of current interest. An excellent program of papers and discussions in its five major areas of activity (Aeromedical, Wind Tunnel, Structures, Flight Test, and Documentation) has been assembled from the NATO nations, and the roster of delegates reads like an international "Who's Who in Aviation."

Dr. von Kármán and his associates have performed a signal service in organizing and implementing the AGARD idea. It is always very gratifying to those of us of the Institute to be invited to participate. We do what we can to assist in the staff functions, and many IAS members participate in the meetings or attend as observers. Specifically, our work with AGARD's Documentation Committee led directly (with Air Force support) to the publication of the International Aeronautical Abstracts, the yellow insert that now appears in every issue of the REVIEW. This service has attracted wide interest all over the world and is in growing demand.

Thus, IAS interests in the international field are steadily expanding. And this is good. Great profit can be derived, *is* being derived. We look toward the day when our activities may even extend beyond present limits. Already there are signs that there are cracks in the so-called Iron Curtain. Perhaps exchange of ideas at the technical level with scientists of the USSR may yet be possible. Possibly we may someday have a Russian lecturer on an IAS program. Possibly an IAS delegation may someday visit a Russian research laboratory. Who knows? S.P.J.

The origin and some of the consequences of aerodynamic heating are discussed, with emphasis on calculation of the rate of transfer of heat from the air into the surface of a high-speed vehicle and on boundary-layer control by surface cooling.

The Problem of Aerodynamic Heating

E. R. van Driest*
North American Aviation, Inc.

Symbols

Variables and Parameters

- x, y = geometrical coordinates parallel and normal to a body surface with origin at leading edge or stagnation point
- u = velocity in x-direction
- c_f = local skin-friction coefficient
- C_f = mean skin-friction coefficient
- h = heat-transfer coefficient, $q_w/(T_r - T_w)$
- ρ = fluid density
- μ = coefficient of fluid viscosity
- k = coefficient of thermal conductivity, height of wire trip
- c_p = specific heat at constant pressure
- γ = ratio of specific heats at constant pressure and constant volume
- T = absolute temperature
- q_w = heat transfer at the wall
- M = Mach Number
- r = recovery factor
- s = Reynolds analogy factor
- $c_{H\delta}$ = Stanton Number, $h/\rho_\delta u_\delta c_p$
- $c_{H\infty}$ = Stanton Number, $h/\rho_\infty u_\infty c_p$
- $Re_{x\delta}$ = Reynolds Number, $\rho_\delta u_\delta x/\mu_\delta$
- $Re_{D\infty}$ = Reynolds Number, $\rho_\infty u_\infty D/\mu_\infty$
- Pr = Prandtl Number, $c_p\mu/k$
- l = mixing length
- n = power in viscosity-temperature power law
- β = constant in $u_\delta = \beta x$
- D = diameter
- ϵ = height of roughness
- δ = thickness of boundary layer
- δ_k^* = displacement thickness of boundary layer at position of wire trip
- u' = root-mean-square of turbulence fluctuations
- $Re_{\delta T}$ = transition Reynolds Number, $\rho_\delta u_\delta x_T/\mu_\delta$
- Re_{δ_0} = transition Reynolds Number on a smooth body

Subscripts

- δ = condition at outer edge of boundary layer
- w = condition at wall
- ∞ = conditions in undisturbed flow
- r = recovery
- T = transition
- 0 = condition for smooth body or in tunnel supply chamber
- $*$ = ratio to free-stream conditions
- ins = insulated plate

Presented at the Aerodynamic Heating: Aerodynamic Aspects Session, National Summer Meeting, IAS, Los Angeles, June 18–21, 1956.

* Chief Scientist, Missile Development Division.

Introduction

Aerodynamic heating is the heating of an object as a result of the flow of air at high speed about that object. Friction between the fluid filaments while they stream along the body and compression at and near the stagnation regions of forward surfaces convert the kinetic energy of motion into heat within a thin layer of air which blankets the body. Such a region is shown in Fig. 1. The temperature of this layer increases with the square of the speed so that, already at a Mach Number of 3, the boundary-layer temperature attains a value of about 600°F. Since this temperature is concentrated in the air at the surface of the aircraft, heat will flow readily from the boundary layer to the aircraft, the ease with which it flows increasing also with speed. Because of the increase of heat transfer with speed, it appears that a "thermal barrier" exists much as it appeared in the past that a "sonic barrier" existed. However, like the sonic (drag) barrier, which was eventually hurdled by informed design practices, it is believed that the thermal barrier can also be overcome by realistic and proper engineering design. The problems differ somewhat in that the drag barrier existed over a narrow band of Mach Number, whereas the thermal barrier does not occur over a limited range of Mach Number but rather tends to increase in severity as Mach Number is increased. In attempting to solve the thermal problem, the first question that arises is: What is the rate at which heat enters the surface of a high-speed vehicle? Subsequent questions are: Where does the heat go? What happens when the heat gets there? How can the designer live with it?

The first question, which must be answered by the aerothermodynamicist, will be generally dealt with in this paper. The subsequent questions must be engaged by a host of engineers from the structures man through the detail designer.

Status of Calculation Procedure for Aerodynamic Heating

The rate of heat transfer from a hot boundary layer to a cooler wall follows the modified Newtonian law

$$q_w = h(T_r - T_w) \tag{1}$$

where T_r is the recovery boundary-layer temperature, T_w the wall temperature, and h the heat-transfer coefficient. The boundary-layer temperature T_r is usually written in terms of a recovery factor r defined by

$$T_r = T_\delta\{1 + r\cdot[(\gamma - 1)/2]M_\delta^2\} \tag{2}$$

where T_δ and M_δ are the local stream temperature and Mach Number, respectively, at the outer edge of the boundary layer, and γ the ratio of the specific heat at constant pressure c_p to the specific heat at constant volume c_v. Furthermore, the heat-transfer coefficient h can be expressed in dimensionless form by

$$c_{H\delta} = h/\rho_\delta u_\delta c_p \tag{3}$$

which is called the Stanton Number. The Stanton Number is proportional to the local skin-friction coefficient $c_{f\delta}$ in a modified Reynolds analogy form

$$c_{H\delta} = (1/s)\cdot(c_{f_\delta}/2) \tag{4}$$

In Eq. (3), the symbols ρ_δ and u_δ are the density and velocity, respectively, just outside the boundary layer, and, in Eq. (4), the term s is called the Reynolds analogy factor. Eq. (1) may now be written as

$$q_w = c_{H\delta}\rho_\delta u_\delta c_p\left[T_\delta\left(1 + r\cdot\frac{\gamma - 1}{2}M_\delta^2\right) - T_w\right] \tag{5}$$

Thus, according to Eq. (5), it is necessary to know the Stanton Number $c_{H\delta}$ and the recovery factor r in order to compute the rate of heat transfer. Now r will vary from about 0.85 for laminar flow to about 0.88 for turbulent flow, so that the exact value will not make or break a design. The coefficient $c_{H\delta}$, on the other hand, varies considerably from laminar to turbulent flow and furthermore, for turbulent flow, is a strong function of Mach Number. Also, the point of transition from laminar to turbulent flow is not yet predictable. Therefore, so long as $c_{H\delta}$ is indefinite, it appears that the state of the art of heat-transfer calculation is rather shaky. Nevertheless, with certain assumptions, calculations can be made. Calculation of heat transfer with laminar flow is felt to be quite reliable, since the fundamental equations are amenable to mathematical solution. Calculation of heat transfer involving entirely turbulent flow is less reliable, because the physical phenomenon is not well understood. Least reliable of all is the calculation of heat transfer in the transition range, since little is known about the location of the transition point. The state of knowledge in each of the above areas will now be discussed.

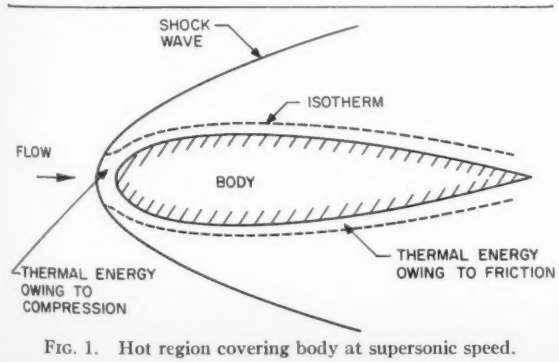

FIG. 1. Hot region covering body at supersonic speed.

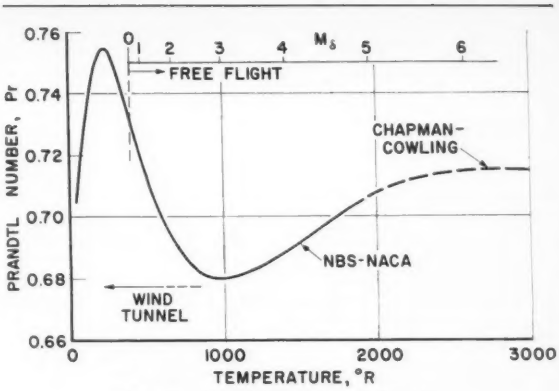

FIG. 2. Prandtl Number of dry air.

FLAT PLATES

Although pressure and temperature gradients along the surface of a body affect heat transfer appreciably, the primary constant-free-stream-velocity boundary layer with constant wall temperature will be discussed first. Later the heat transfer to blunt bodies will be described.

The heat-transfer coefficient depends also upon whether the boundary layer is laminar, turbulent, or transitional. Since laminar-flow heating rates are significantly lower than turbulent rates, it is important to study the laminar results, owing to the possibility of maintaining laminar flow by suitable control.

Laminar Flow

As mentioned above, the two necessary items to be known for heat-transfer calculation are the recovery factor and the Stanton Number.

Recovery Factor—In order to compute the recovery factor, it is necessary to solve the momentum and energy equations for the boundary layer simultaneously. This has been done carefully for completely variable properties, such as density, viscosity, Prandtl Number, and specific heat.[1] Since the Prandtl Number $(c_p\mu/k)$ is the most important parameter influencing the recovery factor and since it varies strongly with temperature, it is indicated in Fig. 2 (cf. reference 1). Fig. 3 shows the theoretical results for recovery factor for a plate in free flight at zero angle of attack with $T_\delta = 400°$R. In the Figure the Prandtl Number $Pr_\delta = (c_p\mu/k)_\delta$, where k is the coefficient of thermal conductivity. Subscript *ins* denotes insulated-plate condition. It is first noted from the Figure that the recovery factor is not constant but rather a function of both Mach Number and heat transfer. This variation is due largely, although not entirely, to Prandtl Number variation within the boundary layer. Second, it is seen that the numerical spread of r is only from about 0.82 to about 0.85. And

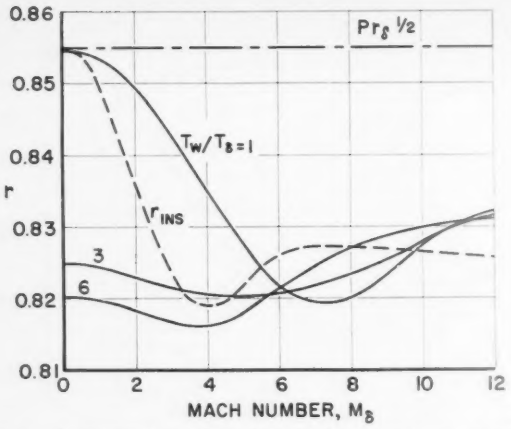

FIG. 3. Recovery factor for a laminar boundary layer on a flat plate in free flight.

third, one notes that the quantity of $Pr_\delta^{1/2}$ represents that range within engineering accuracy and can be used for most engineering calculations. It is interesting to note that $Pr_\delta^{1/2}$ is very closely equal to r only at $M_\delta = 0$ and $T_w/T_\delta = 1$.

When experimental work is conducted in a wind tunnel, the free-stream condition becomes cold, unless the air is heated. At any rate, during such experimentation, one is usually operating at the lower temperature end of the scale for the various property variations. For a wind tunnel with various degrees of heating, the exact recovery-factor calculations are plotted in Fig. 4, a numerical value of 0.85 again roughly representing the results. These calculations have been substantiated by experimental measurements at the Naval Ordnance Laboratory[2] and the Massachusetts Institute of Technology,[3] as shown in Fig. 5. Apparently the recovery factor for laminar flow is well accounted for.

Stanton Number—As with the recovery factor, the Stanton Number can be computed exactly for laminar flow, including variable properties. The results for flat plates in free flight and in heated wind tunnels are given in Figs. 6 and 7, respectively. The curves of Fig. 7 represent only the insulated plate case. Comparison of the figures for the insulated plate case show that the effect of Mach Number is much smaller in the wind tunnel that in free flight, certainly at the lower tunnel supply temperatures. Thus, at supply temperatures around 100°F., one could hardly expect to see any effect of Mach Number on wind-tunnel heat-transfer data. This conclusion, as well as fair substantiation of the theory, is indicated in Fig. 8 in which are plotted NOL heat-transfer data[2] corresponding to some of the recovery-factor data in Fig. 5.

As far as laminar flow is concerned, it appears that, for moderate supersonic speeds, the theory can be depended upon to yield accurate heat-transfer coefficients, in spite of the scatter of experimental data owing to the difficulty of measuring the generally low laminar-flow heat-transfer rates on flat plates. This conclusion follows because the analysis is exact and the fluid properties are well known at moderate temperatures.

Application to Cones—The above results for flat plates can be applied to cones in axial flow by merely multiplying the flat-plate heat-transfer coefficient at the same local Mach Number, local Reynolds Number, and wall-to-local-free-stream temperature ratio by $\sqrt{3}$.

Turbulent Flow

Until the day comes when the boundary layer can be controlled and held laminar, it will be necessary to live with a certain amount of turbulent flow. Indeed, for insurance, the designer should assume fully turbulent flow. The bitter consequences of such an assumption will be seen later in Fig. 22 where it is seen that, for a Reynolds Number of 10^7 and moderate supersonic Mach Numbers, the turbulent heat-transfer coefficient is about 10 times the laminar value.

Recovery Factor—With turbulent flow, the energy equation (in terms of mean quantities) can still be integrated, and a general expression for recovery factor in terms of shear stress (to be obtained from the momentum equation) derived.[1, 4] However, with turbulent flow, the momentum equation cannot be integrated for lack of complete knowledge of the turbulent mechanism, and therefore simplifying assumptions concerning shear and velocity distribution must be made. Assuming a linear shear distribution with distance from the wall and dividing the viscous subregion into the laminar and transitional layers as von Kármán had done,[5] one arrives at the following formula for recovery factor:[1, 4]

$$r = Pr_T\left[1 + \frac{2}{K}\sqrt{\frac{c_f}{2}}(1 - Pr_T)\left[\frac{\pi^2}{6} + \frac{3}{2}(1 - Pr_T)\right] + 25\cdot\frac{c_f}{2}\left\{\left(\frac{Pr_L}{Pr_T} - 1\right) + 2\ln\left[1 + \frac{5}{6}\left(\frac{Pr_L}{Pr_T} - 1\right)\right] + \ln 6\cdot\ln\left[1 + \frac{7}{8}\left(\frac{Pr_L}{Pr_T} - 1\right)\right] - \ln 6\cdot\ln\left[1 + \frac{1}{4}\left(\frac{Pr_L}{Pr_T} - 1\right)\right]\right\}\right] \quad (6)$$

for $0.7 \leqq Pr_T \leqq 1$. In this expression, Pr_L and Pr_T represent the laminar and turbulent Prandtl Numbers, respectively, and K is the mixing length proportionality

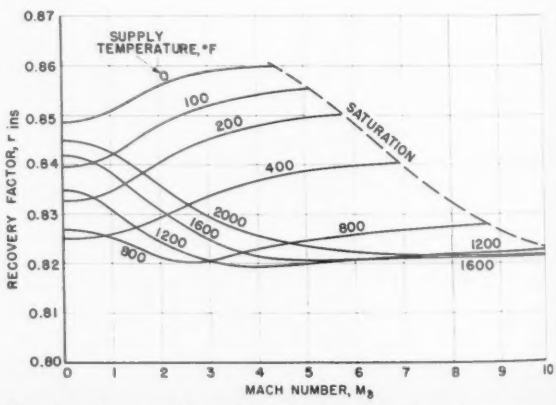

FIG. 4. Recovery factor for a laminar boundary layer on an insulated flat plate in a wind tunnel for air.

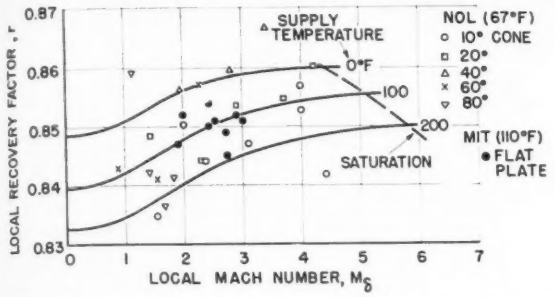

FIG. 5. Comparison of theory and experiment on recovery factor for laminar boundary layers on flat plates and cones in a wind tunnel.

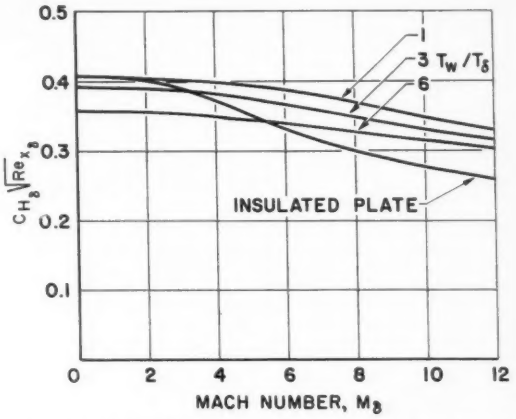

FIG. 6. Local heat-transfer coefficient for a laminar boundary layer on a flat plate in free flight.

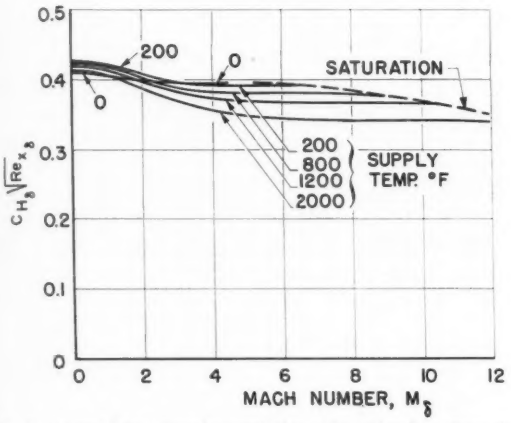

FIG. 7. Local heat-transfer coefficients for a laminar boundary layer on an insulated flat plate in a wind tunnel.

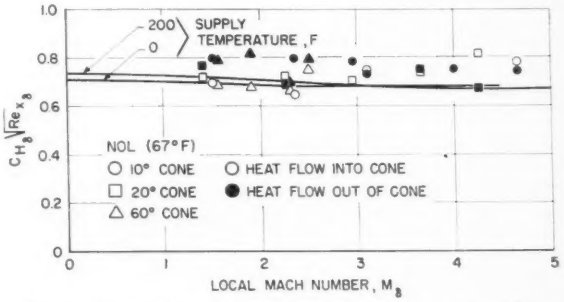

FIG. 8. Comparison of theory and experiment on local heat-transfer coefficient for laminar boundary layers on cones in a wind tunnel.

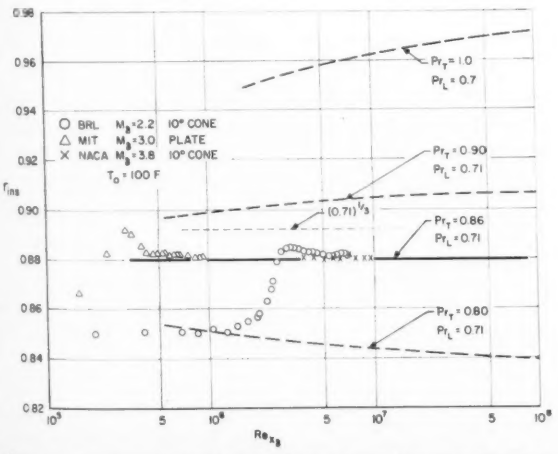

FIG. 9. Recovery factor for a turbulent boundary on a flat plate as a function of Reynolds Number for air ($M_\delta = 0$).

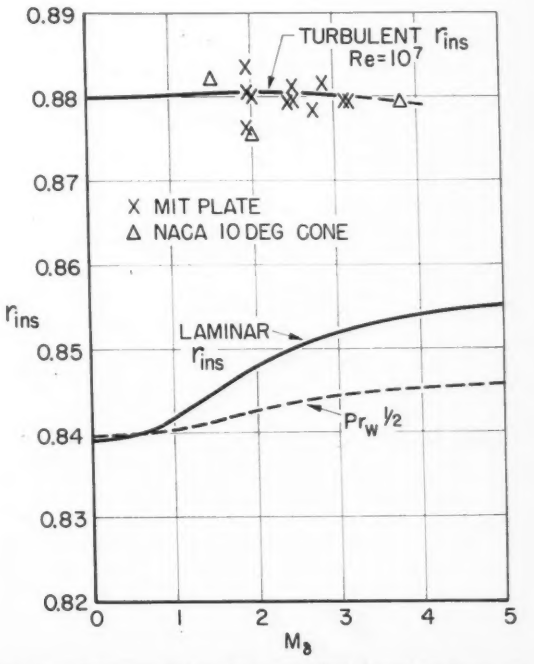

FIG. 10. Recovery factor for a turbulent boundary layer on a flat plate in air in a wind tunnel.

factor usually taken at 0.4. Although the expression was derived for incompressible flow, it can yield approximate trends for compressible flow. With laminar flow, the recovery factor was independent of Reynolds Number. When the recovery factor as well as the turbulent Prandtl Number are assumed independent of Reynolds Number in turbulent flow, it will be uniquely necessary that $r = 0.88$ and $Pr_T = 0.86$. Hence, out of these assumptions comes also a numerical value for the turbulent Prandtl Number.

Fig. 9 shows Eq. (6) for various values of Pr_T, but with $Pr_L = 0.71$. Also plotted in Fig. 9 are some experimental data from the Ballistics Research Laboratory,[6] M.I.T.,[3] and NACA.[7] The independence of the recovery-factor data with Reynolds Number appears to be a good assumption, and the data fall close to the theoretical value of $r = 0.88$ corresponding to $Pr_T = 0.86$. It is seen that Squire's $Pr_L^{1/3} = (0.71)^{1/3} = 0.892$ is a good approximation to Eq. (6) for $Pr_T = 0.86$.

Eq. (6) for recovery factor can be extended to compressible flow, approximately, when wall conditions are introduced in the friction coefficient. Thus the factor

$$\left(1 + r \cdot \frac{\gamma - 1}{2} M_\delta^2\right)$$

should be multiplied into c_f wherever c_f appears in Eq. (6), and then the compressible flow values of c_f are used (see Fig. 13). It will then be found that the recovery factor is essentially independent

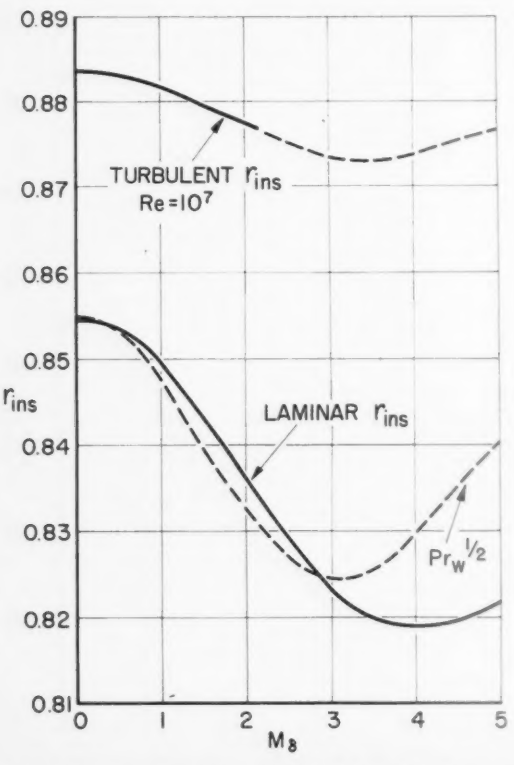

FIG. 11. Recovery factor for a turbulent boundary layer on a flat plate in free flight in air.

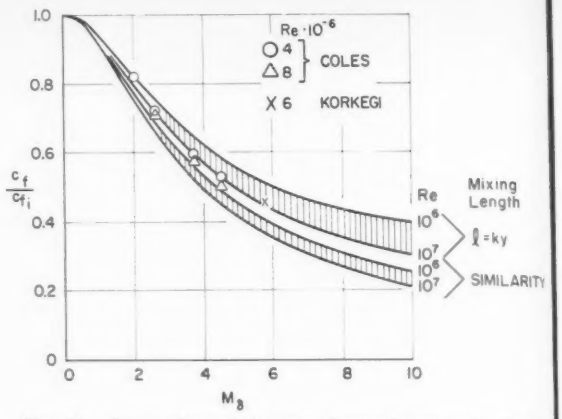

FIG. 12. Comparison of theory and experiment on local skin-friction coefficient for turbulent boundary layers on insulated flat plates.

of Mach Number at least for moderate supersonic speeds, therefore justifying the use of the data in Fig. 9 when the theory was plotted for $M_\delta = 0$. This independence is indicated in Fig. 10 where Eq. (6) (with $Pr_T = 0.86$) is plotted vs. Mach Number for a flat plate in a wind tunnel at a Reynolds Number of 10^7. Fig. 11 shows the variation of recovery factor for a flat plate in free flight in the atmosphere. The stronger variation with Mach Number is due essentially to the stronger variation in laminar Prandtl Number in free flight than in the unheated wind tunnel. The laminar-flow recovery factors are shown in Figs. 10 and 11 for comparison purposes.

In conclusion, it appears that a recovery factor of 0.90 is accurate enough for most engineering calculations assuming a turbulent boundary layer.

Stanton Number—As mentioned above, it is not possible to integrate the momentum equation for turbulent motion, and therefore other means must be utilized in order to include the role of the momentum law in the calculation of heat transfer. What is wanted from the momentum equation is the momentum defect, or, rather, the friction coefficient, for use in Eq. (4). Also, as seen from Eq. (4), it is necessary to compute the Reynolds analogy factor s, which, like the recovery factor, will depend upon the friction.

(*a*) *Friction coefficient:* A semianalytical method of obtaining the local friction coefficient for high-speed turbulent flow is through an extension of von Kármán's mixing-length incompressible-flow theory to take into account density and viscosity variation with temperature. The result is[1, 4]

$$\frac{0.242}{c_{f_\delta}^{1/2}\left(\frac{\gamma - 1}{2} M_\delta^2\right)^{1/2}} (\sin^{-1}\alpha + \sin^{-1}\beta) =$$

$$0.41 + \log_{10}(Re_{x_\delta} \cdot c_{f_\delta}) - f(n)\log_{10}(T_w/T_\delta) \quad (7)$$

where

$$\alpha = (2A^2 - B)/(B^2 + 4A^2)^{1/2}$$
$$\beta = B/(B^2 + 4A^2)^{1/2}$$

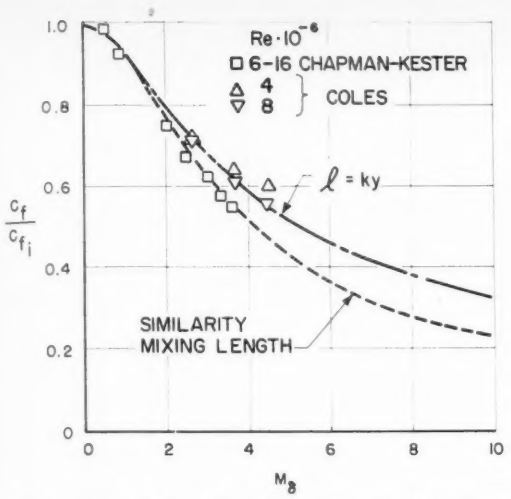

FIG. 13. Effect of Mach Number on mean skin-friction coefficient for insulated surfaces in wind tunnels at Reynolds Numbers of approximately 10^7.

$$A^2 = \left(\frac{\gamma - 1}{2} M_\delta^2\right) \Big/ (T_w/T_\delta)$$

$$B = \left[\left(1 + \frac{\gamma - 1}{2} M_\delta^2\right) \Big/ (T_w/T_\delta)\right] - 1$$

and in which $f(n)$ is a function of the exponent n in the power viscosity law $\mu = \text{const.} \cdot T^n$. It will be found that $f(n)$ depends upon the law assumed for mixing length l. Thus, when the Prandtl mixing length $l = Ky$ is assumed, where y is the distance from the wall normal to the flow, then $f(n) = (1/2) + n$; and when the von Kármán mixing length $l = K(du/dy)/(d^2u/dy^2)$ is assumed, then $f(n) = n$.

There seems to be no really valid theoretical reason for favoring either assumption for mixing length. For $T_w/T_\delta = 1$, both assumptions lead to the same result. However, for $T_w/T_\delta \neq 1$, the above difference in $f(n)$ appears. Therefore, it seems that the choice of mixing-length law must be left to experiment.

Fig. 12 shows a plot of the theory for local skin friction on an insulated plate using the two choices of mixing-length law. The ordinate is the ratio of compressible to incompressible friction. Also plotted are floating-element data of Coles[8] and Korkegi.[9] The data seem to fall between the two mixing-length choices. (Of course, it must be considered that probably too much is being expected of the mixing-length theory itself.)

Another test of the theory can be made using average skin-friction data. The equation for the average friction coefficient defined by

$$C_{f_\delta} = \frac{1}{x} \int_0^x c_{f_\delta}\, dx$$

is

$$\frac{0.242}{C_{f_\delta}^{1/2} \left(\frac{\gamma - 1}{2} \cdot M_\delta^2\right)^{1/2}} (\sin^{-1} \alpha + \sin^{-1} \beta) =$$

$$\log_{10}(Re_{x_\delta} \cdot C_{f_\delta}) - f(n) \log_{10}(T_w/T_\delta) \quad (8)$$

For insulated plates, the ratio of compressible to incompressible average friction is shown in Fig. 13. The directly measured mean data of Chapman and Kester[10] and the integrated local data of Coles[8] are also plotted in the Figure. It appears that these sets of data are not sufficiently consistent to allow a decision on the mixing-length law if the mixing-length theory is to be adhered to. More experiments are required, particularly at hypersonic Mach Numbers where the effects are greatest.

A further check on the theory can be obtained from free-flight data. Under transient conditions of free flight, the wall-to-free-stream temperature ratio T_w/T_δ is close to unity, whereupon the last term in Eq. (8) and the effect of $f(n)$ disappears. For $T_w/T_\delta = 1$, the effect of $f(n)$ would also disappear from Eq. (7). In Fig. 14 is plotted the mean-friction theory of Eq. (8), assuming the similarity law for mixing length—i.e., $f(n) = n$, where n is taken as 0.76. Also plotted in the Figure are free-flight total-friction-drag data of Sommer and Short.[11] The theory and data appear to agree well for $T_w/T_\delta = 1$.

(*b*) *Reynolds analogy factor:* Fundamentally, the key to the rate of heat transfer within a substance is in the availability of energy to be transported and in the ability of the substance to transport that energy. This is expressed by the Prandtl Number, which is a dimensionless grouping of the specific heat thermal conductivity, and by viscosity—i.e., $Pr = c_p\mu/k$. Thus the Prandtl Number should strongly influence the convective heat-transfer processes. Indeed, the Prandtl Number is embodied mainly in the Reynolds analogy factor s of Eq. (4), with the Prandtl Number having a small effect in turn upon the friction coefficient c_f.

As with the recovery factor, integration of the energy equation also yields a general expression for the Reynolds analogy factor.[1, 4] And then, again, when a linear shear distribution with distance from the wall is assumed and the boundary layer is divided into a laminar sublayer, a transitional layer, and a wholly

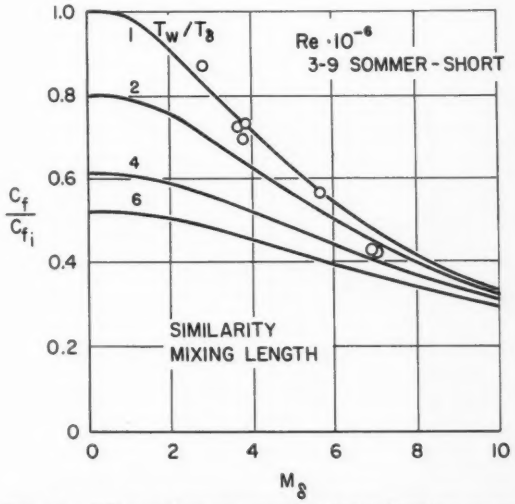

FIG. 14. Effect of heat transfer and Mach Number on mean skin friction coefficient for a body in free flight in a wind tunnel at Reynolds Numbers of approximately 10^7.

turbulent layer, one arrives at the formula[1, 4]

$$s = Pr_T\left[1 + 5\sqrt{\frac{c_f}{2}}\left\{\frac{1}{5K}(1 - Pr_T)\times\left[\frac{\pi^2}{6} + \frac{3}{2}(1 - Pr_T)\right] + \left(\frac{Pr_L}{Pr_T} - 1\right) + \ln\left[1 + \frac{5}{6}\left(\frac{Pr_L}{Pr_T} - 1\right)\right]\right\}\right] \quad (9)$$

for $0.7 \leqq Pr_T \leqq 1$. This formula reduces to the von Kármán formula[5] when it is assumed that $Pr_T = 1$. Also for $Pr_L = Pr_T = 1$, then $s = 1$, which gives the well-known Reynolds analogy formula—viz., $c_H = c_f/2$.

Eq. (9) is presented as the solid line in Fig. 15, upon substitution of the turbulent Prandtl Number 0.86 [determined from Eq. (6)] and a typical laminar Prandtl Number 0.71. Also shown in the Figure are the formulation[5] of von Kármán ($Pr_T = 1$) and the estimate of Colburn ($s = Pr_L^{2/3}$). Thus, it is seen numerically(for the particular example chosen where $Pr_L = 0.71$) that, while Colburn's estimate is a good approximation to Eq. (9) with $Pr_T = 0.86$, von Kármán's formulation yields a result significantly higher.

The effect of compressibility on s can also be estimated in the same manner as with r. The results are plotted in Figs. 16 and 17 for a flat plate in free flight and in a wind tunnel, respectively, using the laminar Prandtl Number of Fig. 2.

The Stanton Number can now be computed using $c_{H_\delta} = (1/s)\cdot(c_{f_\delta}/2)$, where s is taken from Fig. 15, and c_{f_δ} is obtained from Eq. (7). Whence the calculated Stanton Number can be compared with heat-transfer data with an eye to determine what mixing-length law should best be used.

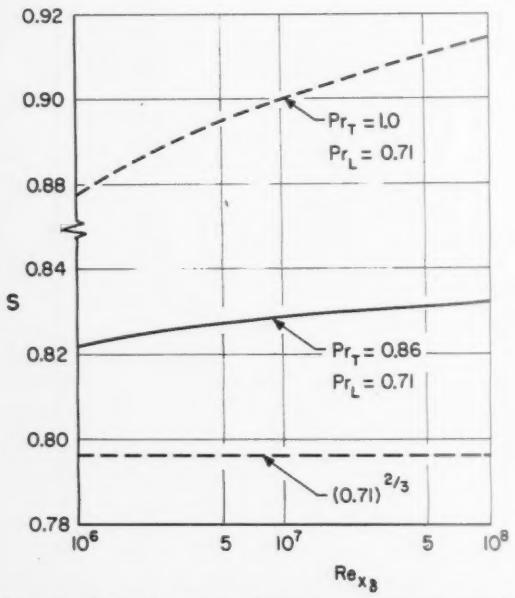

FIG. 15. Reynolds analogy factor for a turbulent boundary layer on a flat plate in air as a function of Reynolds Number ($M_\delta = 0$).

Heat-transfer data obtained at M.I.T.[12] for supersonic Mach Numbers of 2.0, 2.5, and 3.0 are plotted vs. Reynolds Number in Figs. 18, 19, and 20, respectively. Theoretical curves using $s = 0.825$ from Fig. 17 and the similarity law for mixing length [$f(n) = n$] seem to fit the data well. When these data, as well as other data, are plotted vs. Mach Number as in Fig. 21, an apparent favoring of data toward the similarity law is observable.

A discussion of heat transfer would not be complete without a comparison of the results for both laminar and turbulent flow. Fig. 22 gives the Stanton Number for an insulated flat plate in free flight. The laminar-flow curves are obtained from Fig. 6, and the turbulent-flow curves are from Eqs. (4) and (7) assuming $s = 0.825$ and $f(n) = n$. It is significant to note that the turbulent heat transfer is of the order of 10 times the laminar heat transfer.

An apparent difficulty in computing heat transfer is that the rate depends also upon the surface temperature often desired in the first place. Therefore, a tedious iteration process, discouraging to the engineer, must be resorted to. For engineering purposes, it is then convenient to have the Stanton Number as a function of Reynolds Number, Mach Number, and wall-to-free-stream temperature ratio in the form of a nomograph. This has been done in Fig. 23 using $s = 0.825$ and in Eq. (7) with $f(n) = n$. Thus, not only is the basic equation solved for a given wall temperature, but the Stanton Number can be quickly adjusted for changing conditions.

It is pointed out that the local and average values of the skin-friction coefficient are also determined in the nomograph of Fig. 23. Since these are based on the similarity law [$f(n) = n$] in Eqs. (7) and (8), the performance engineer should proceed with caution in the light of the spread of data in Fig. 13. For drag calculation, it would appear safer to use the linear mixing-length assumption.

Application to Cones—The turbulent heat transfer on a flat plate will equal that on a cone in axial flow for the same local Mach Number and wall-to-local-free-stream temperature ratio, provided the heat-transfer coefficient on the plate is computed for a Reynolds Number of one half that on the cone.

BLUNT BODIES

Laminar Flow

The above results for flat plates represented the results for a boundary layer with constant external velocity. The solution for laminar flow was found to be of the form $c_{H_\delta}\sqrt{Re_{x_\delta}} = f_1(M_\delta, T_w/T_\delta, Pr_\delta)$, whence

$$\left.\begin{aligned} q_{w_{plate}} &= c_{H_\delta}\rho_\delta u_\delta c_p(T_r - T_w) \\ &= \frac{f_1}{\sqrt{\dfrac{\rho_\delta u_\delta x}{\mu_\delta}}}\cdot\rho_\delta u_\delta c_p(T_r - T_w) \end{aligned}\right\} \quad (10)$$

In fact, for incompressible flow,

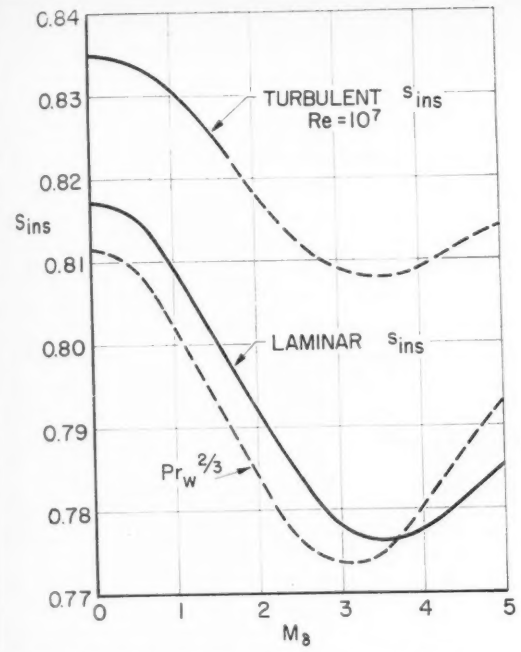

FIG. 16. Reynolds analogy factor for a turbulent boundary layer on a plate in free flight in air.

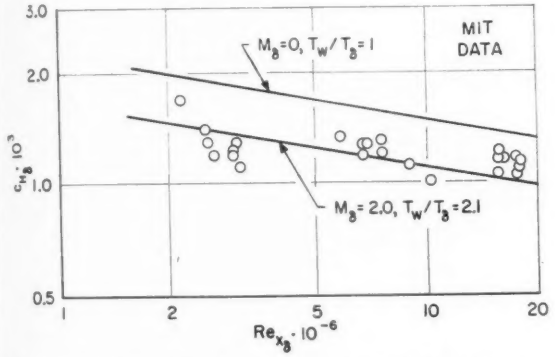

FIG. 18. Local heat-transfer coefficient for a turbulent boundary layer on a heated flat plate ($M_\delta = 2.0$ and $T_w/T_\delta = 2.1$).

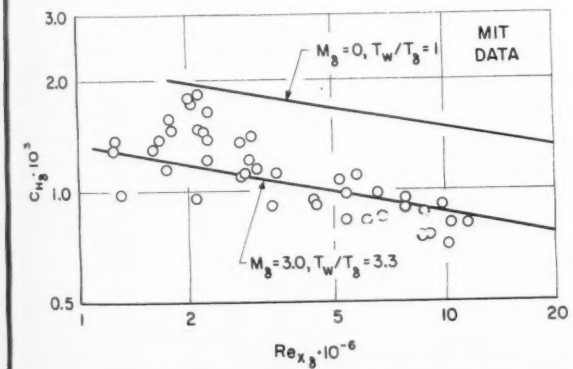

FIG. 20. Local heat-transfer coefficient for a turbulent boundary layer on a heated flat plate ($M_\delta = 3.0$ and $T_w/T_\delta = 3.3$).

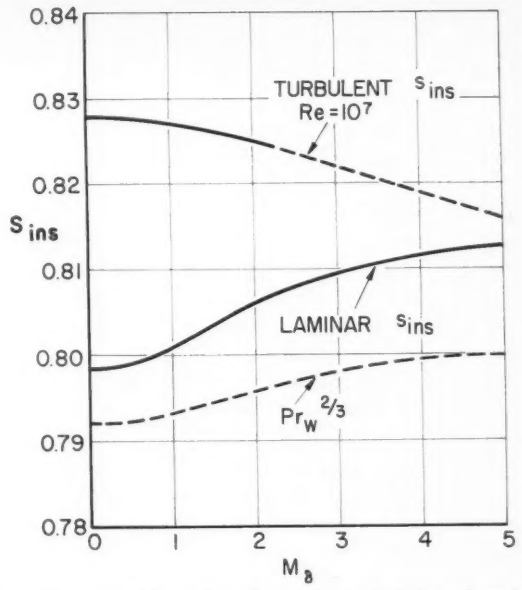

FIG. 17. Reynolds analogy factor for a turbulent boundary layer on a flat plate in air in a wind tunnel.

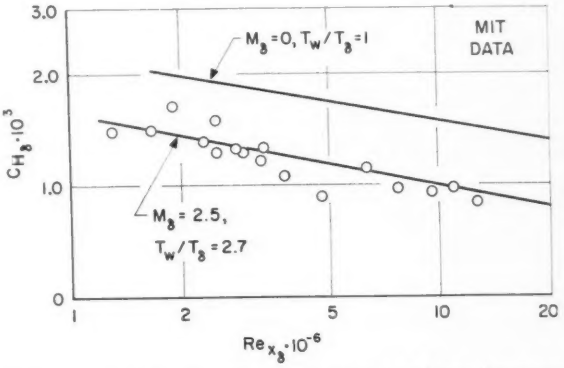

FIG. 19. Local heat-transfer coefficient for a turbulent boundary layer on a heated flat plate ($M_\delta = 2.5$ and $T_w/T_\delta = 2.7$).

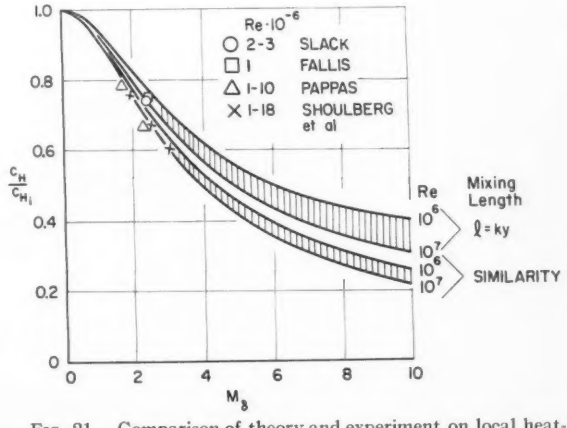

FIG. 21. Comparison of theory and experiment on local heat-transfer coefficient for turbulent boundary layers on near-insulated flat plates.

$$f_1 = c_{H_\delta}\sqrt{Re_{x_\delta}} = 0.332Pr^{-2/3} \tag{11}$$

in which $Re_{x_\delta} = \rho_\delta u_\delta x/\mu_\delta$. It thus follows that as the leading edge of the plate is approached—i.e., $x \to 0$—the heat-transfer rate becomes exceedingly large. This is a consequence of assuming the boundary layer thin in the first place, an assumption which is not true near the leading edge. However, regardless of the accuracy of the theory, it is evident that the heat-transfer rate would be greatest at the leading edge of a plate or at the point of a cone. Now it is known that the heating rate at the stagnation point is finite. Hence, it appears proper to blunt leading edges or noses in order to relieve the heat-transfer rate at those locations.

In the stagnation regions of cylinders and spheres, the heat-transfer problem can be solved exactly for incompressible flow. However, with high-speed flow, the problem is not amenable to exact solution. Nevertheless, approximate calculations can be made when it is assumed that the flow behind the bow shock wave is incompressible.

The formula for the laminar heat-transfer rate in an incompressible stagnation region is again found to be of the form

$$q_{w_{stag}} = \frac{f_2}{\sqrt{\dfrac{\rho_\delta u_\delta x}{\mu_\delta}}} \cdot \rho_\delta u_\delta c_p(T_r - T_w) \tag{12}$$

in which x is measured along the surface from the stagnation point, and where f_2 depends also upon the forebody shape. For cylinders,[13]

$$f_2 = c_{H_\delta}\sqrt{Re_{x_\delta}} = 0.570\ Pr^{-0.6} \tag{13}$$

and for spheres,[14]

$$f_2 = 0.763Pr^{-0.6} \tag{14}$$

Of course, for incompressible flow, $\rho_\delta = \rho_\infty$, $\mu_\delta = \mu_\infty$, and $T_r = T_\delta = T_\infty$. Now, unlike the flat plate where the velocity u_δ was constant along the outer edge of the boundary layer, in the stagnation region u_δ varies with x along the surface. In fact, Eq. (12) with Eqs. (13) and (14) were derived using $u_\delta = \beta x$, where β is a constant. It turns out that for incompressible flow $\beta = 4u_\infty/D$ for cylinders and $3u_\infty/D$ for spheres, where the D's are the respective diameters, and u_∞ is the velocity of the undisturbed stream.

For supersonic flow whereby a shock wave stands in front of the body and forms a region of subsonic flow around the stagnation point, it is still found,[15] from measurement of pressure and calculation of velocity, that $u_\delta = \beta x$, where β is then a function only of the undisturbed Mach Number M_∞ before the shock wave. Hence, since ρ_δ and μ_δ are relatively constant in the subsonic region behind the shock, $u_\delta = \beta x$ can be used in Eq. (12) with either Eq. (13) or (14), for both subsonic and supersonic flow. Thus

$$\left.\begin{aligned} q_{w_{stag}} &= \frac{f_2}{\sqrt{\dfrac{\rho_\delta \beta x^2}{\mu_\delta}}} \cdot \rho_\delta \cdot \beta x \cdot c_p(T_r - T_w) \\ &= f_2\sqrt{\beta \rho_\delta \mu_\delta}\ c_p(T_r - T_w) \end{aligned}\right\} \tag{15}$$

from which it is generally concluded that in subsonic as well as in supersonic flow, the heat-transfer rate is a constant independent of x in the immediate neighborhood of the stagnation point. As stated above, for incompressible flow—i.e., $M_\infty = 0$, $\beta = 4u_\infty/D$ for the cylindrical edges of airfoils and $3u_\infty/D$ for the tangent spheres of axisymmetric noses. However, with supersonic flow, a practical solution for β can be obtained when the Newtonian flow is assumed, whence

$$\left.\begin{aligned} \beta &= \frac{u_\infty}{D}\left\{8\,\frac{[(\gamma-1)M_\infty^2+2]}{(\gamma+1)M_\infty^2} \cdot \left[1 + \frac{\gamma-1}{2}\cdot\frac{(\gamma-1)M_\infty^2+2}{2\gamma M_\infty^2-(\gamma-1)}\right]^{-[1/(\gamma-1)]}\right\}^{1/2} \\ &= \frac{u_\infty}{D} f(M_\infty, \gamma) \end{aligned}\right\} \tag{16}$$

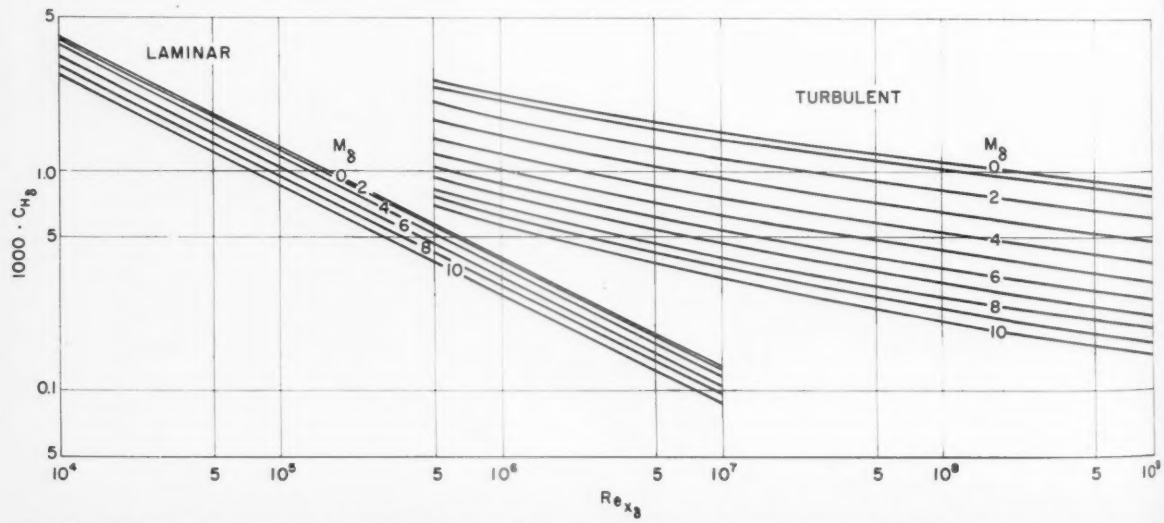

FIG. 22. Heat-transfer coefficient as a function of Reynolds Number and Mach Number for an insulated flat plate in free flight.

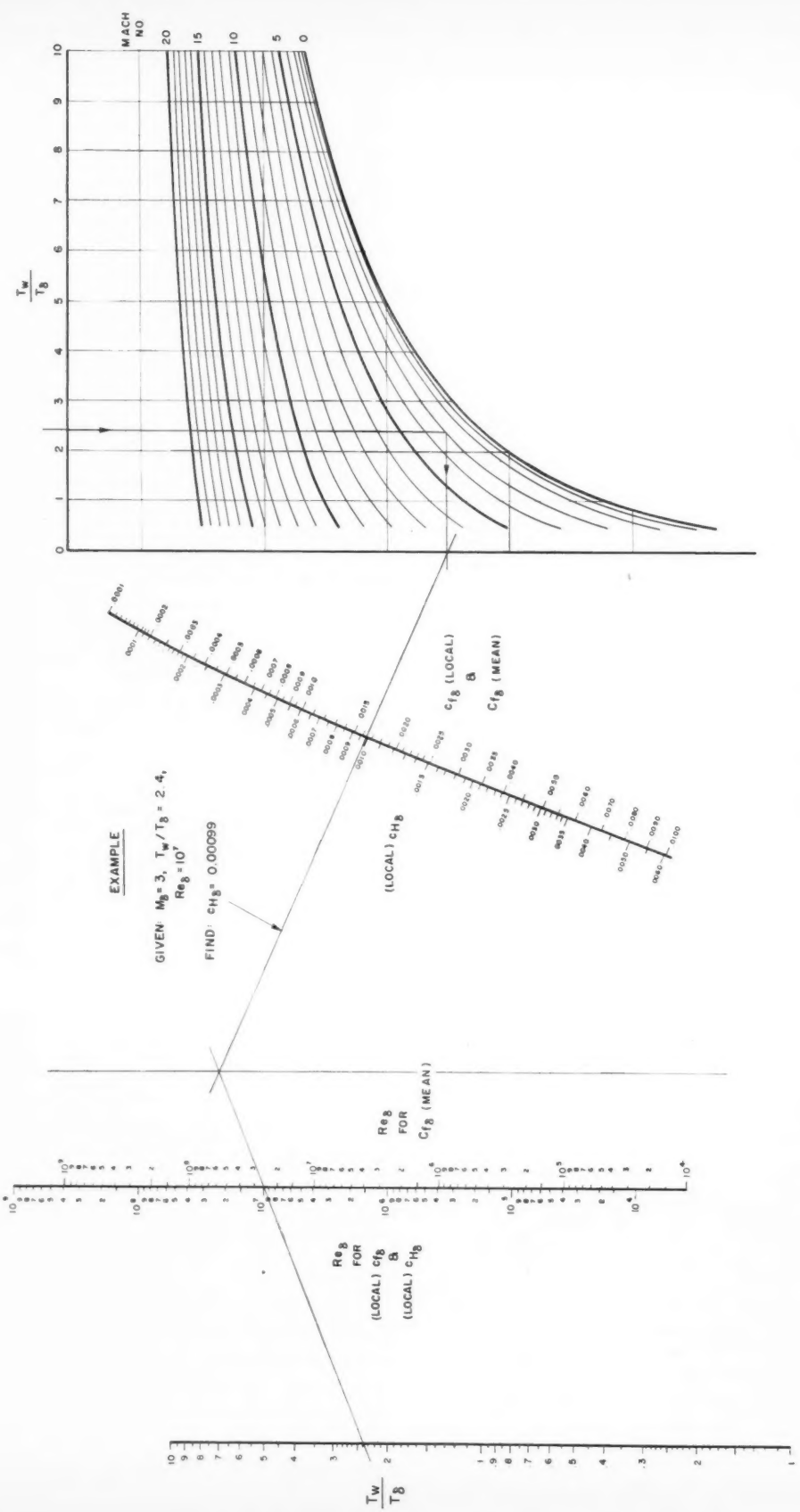

FIG. 23. Nomograph for coefficients of friction and heat transfer of a turbulent boundary layer on a flat plate for air.

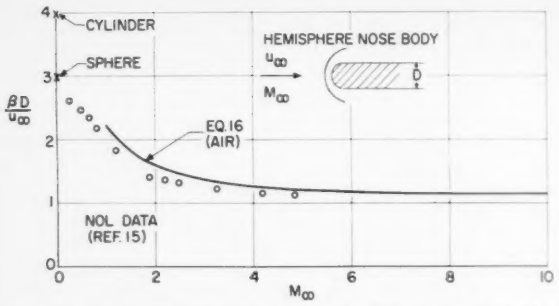

FIG. 24. Local velocity gradient at the stagnation point of a hemisphere-cylinder combination.

in which u_∞ is the velocity ahead of the shock wave.

It is seen from Eq. (15) that the calculation of the heating rate at the stagnation point depends upon the experimental verification of f_2 and β. The validity of Eq. (16) is seen in Fig. 24 where experimental values of β at the stagnation point of a hemispherical nose are plotted. A check on f_2 ($c_{H_\delta}\sqrt{Re_{x_\delta}}$) is obtained in Fig. 25 which shows experimental heat-transfer data[16] around a hemispherical nose at $M_\infty = 1.97$. In spite of the scatter of the data, it appears that Eq. (14) correlates roughly with experiment in the vicinity of the stagnation point. Also plotted in Fig. 25 is a theoretical curve showing how $c_{H_\delta}\sqrt{Re_{x_\delta}}$ decreases as x increases, according to Stine and Wanlass.

As far as aerodynamic heating is concerned, it follows from Eqs. (15) and (16) that $q_{wstag} \sim 1/D^{1/2}$. Hence, by increasing the diameter of tangent cylinder or sphere, one can decrease the heat-transfer rate at the stagnation point.

Since in supersonic flow the temperature will begin to decrease at an increasing rate away from the stagnation region, ρ_δ and μ_δ will likewise decrease, and consequently, according to Eq. (15), q_{wstag} will also begin to fall away from its constant value near the stagnation point. Consequently, the heat transfer is a maximum at the stagnation point so long as laminar flow is assumed.

Turbulent Flow

The above discussion had to do with laminar flow. Indeed, it is expected that the flow at the stagnation point will be laminar, owing to the low Reynolds Numbers there. However, it is possible for the flow to become unstable and eventually turbulent with increasing distance from the stagnation region. This possibility brings to mind the Prandtl-Eiffel experiments. It is recalled that Eiffel's drag data, obtained by dropping spheres from the Eiffel tower, showed the well-known drag-drop for critical sphere Reynolds Numbers above about 300,000. On the other hand, Prandtl's wind-tunnel data did not show a drop. Prandtl explained the phenomenon on the assumption that the boundary layers on Eiffel's spheres became turbulent before separation, whereas his (Prandtl's) boundary layers remained laminar. To prove this, Prandtl induced transition by means of a wire trip, whereupon his drag coefficients agreed with Eiffel's. In the present discussion, however, drag is of no concern but, rather, the increase in heat transfer incurred by transition.

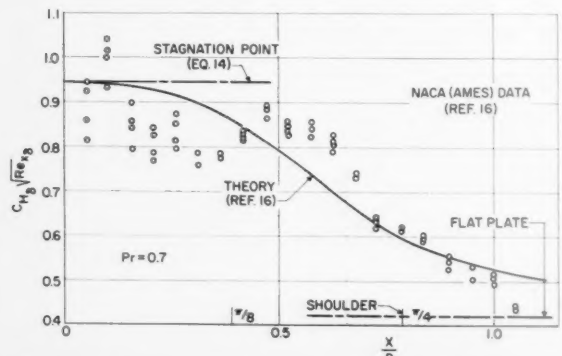

FIG. 25. Local heat-transfer data for a hemispherical nose ($M_\infty = 1.97$).

A theoretical calculation for a turbulent boundary layer can be made when it is assumed that the velocity profile remains similar in the region of the stagnation point. It is also assumed that the flow is fully turbulent in spite of the low Reynolds Numbers there; furthermore, that the turbulence is generated in the boundary layer near the wall, being produced by either roughness or external disturbances which are amplified as they enter the boundary-layer region.

For incompressible flow in the neighborhood of the stagnation point, the heat-transfer rate is then found to be given by[17]

$$q_{wstag} = \frac{f_3}{\left(\frac{\rho_\delta u_\delta x}{\mu_\delta}\right)^{1/5}} \cdot \rho_\delta u_\delta c_p (T_r - T_w) \qquad (17)$$

in which for cylinders

$$f_3 = c_{H_\delta}(Re_{x_\delta})^{1/5} = 0.040 Pr^{-(2/3)} \qquad (18)$$

and for spheres

$$f_3 = 0.042 Pr^{-(2/3)} \qquad (19)$$

It will be recalled that the flat-plate result, assuming a power law for velocity profile, is also of the form

$$q_{wplate} = \frac{f_4}{\left(\frac{\rho_\delta u_\delta x}{\mu_\delta}\right)^{1/5}} \cdot \rho_\delta u_\delta c_p (T_r - T_w) \qquad (20)$$

where

$$f_4 = 0.030 Pr^{-(2/3)} \qquad (21)$$

Thus, as with laminar flow, the forms of the equations are the same for flat plates or for stagnation regions. (For the stagnation region, $u_\delta = \beta x$, again.) Also, as with laminar flow, the incompressible-flow results of Eqs. (17–19) will be used for supersonic flow as well, provided the proper value of β is inserted. Thus, for incompressible flow, $\beta = 4u_\infty/D$ for cylinders and $3u_\infty/D$ for spheres, whereas for supersonic flow $\beta = (u_\infty/D)f(M_\infty, \gamma)$.

Substitution of $u_\delta = \beta x$ into Eq. (17) gives

$$q_{w_{stag}} = f_\beta \beta^{1/5} \rho_\delta^{4/5} \mu_\delta^{1/5} x^{3/5} c_p (T_r - T_w) \qquad (22)$$

Hence, it follows that the turbulent heat-transfer rate increases with distance from the stagnation point. However, with supersonic flow, ρ_δ and μ_δ would gradually decrease so that the turbulent heating rate would eventually begin to fall, thus yielding a maximum some place along the surface. Again, the reader is reminded that the turbulent heating rate given by Eq. (22) could prevail only after the flow has become turbulent.

General

A direct indication of the heating rate in the neighborhood of a stagnation point is presented when the equations [Eqs. (15) and (22)] are put in the following form (say for spheres):

$$q_{w_{stag}} = \frac{0.763}{Pr^{0.6}} \left(\frac{\beta D}{u_\infty}\right)^{1/2} \left(\frac{\mu_\infty}{\rho_\infty u_\infty D}\right)^{1/2} \left(\frac{\rho_\delta}{\rho_\infty}\right)^{1/2} \times \left(\frac{\mu_\delta}{u_\infty}\right)^{1/2} \rho_\infty u_\infty c_p (T_r - T_w) \qquad (23)$$

for laminar flow, and

$$q_{w_{stag}} = \frac{0.042}{Pr^{2/3}} \left(\frac{\beta D}{u_\infty}\right)^{4/5} \left(\frac{\mu_\infty}{\rho_\infty u_\infty D}\right)^{1/5} \left(\frac{\rho_\delta}{\rho_\infty}\right)^{4/5} \times \left(\frac{\mu_\delta}{u_\infty}\right)^{1/5} \left(\frac{x}{D}\right)^{3/5} \rho_\infty u_\infty c_p (T_r - T_w) \qquad (24)$$

for turbulent flow. Hence writing

$$q_{w_{stag}} = c_{H_\infty} \rho_\infty u_\infty c_p (T_r - T_w) \qquad (25)$$

then

$$c_{H_{\infty_{stag}}} = 0.763 \left(\frac{\beta D}{u_\infty}\right)^{1/2} \left(\frac{\mu_\infty}{\rho_\infty u_\infty D}\right)^{1/2} \left(\frac{\rho_\delta}{\rho_\infty}\right)^{1/2} \times \left(\frac{\mu_\delta}{\mu_\infty}\right)^{1/2} Pr^{-0.6} \qquad (26)$$

for laminar flow, and

$$c_{H_{\infty_{stag}}} = 0.042 \left(\frac{\beta D}{u_\infty}\right)^{4/5} \left(\frac{\mu_\infty}{\rho_\infty u_\infty D}\right)^{1/5} \left(\frac{\rho_\delta}{\rho_\infty}\right)^{4/5} \times \left(\frac{\mu_\delta}{\mu_\infty}\right)^{1/5} \left(\frac{x}{D}\right)^{3/5} Pr^{-(2/3)} \qquad (27)$$

for turbulent flow.

As stagnation point solutions, Eqs. (26) and (27) are plotted in Figs. 26–28 as asymptotes at $x/D = 0$ for $M_\infty = 3$, $Pr = 0.7$, and $Re_{D_\infty} = 10^5$, 10^6, and 10^7. The value of $\beta D/u_\infty = 1.3$ is taken from Fig. 24, and the ratios ρ_δ/ρ_∞ and μ_δ/μ_∞ are computed from stagnation conditions behind a normal shock.

Since the form of the heat-transfer equations is the same for the stagnation point where $u_\delta = \beta x$ as for a flat plate where u_δ = constant [cf. Eqs. (10) and (12), and (17) and (20)], it appears that a reasonable approximation of the heating rate over the entire face of a blunt body may be gained by substituting the local value of β into Eqs. (26) and (27) and also by allowing the coefficient f to change with β as well as with geometry. For the laminar case, the value of f was taken from the Stine and Wanlass curve of Fig. 25—i.e., $f_2 = c_{H_\delta}\sqrt{Re_{x_\delta}}$. For the turbulent case, f was assumed to change linearly with β, the effect of geometry being negligible—i.e., changing only from 0.040 $Pr^{-2/3}$ to 0.042 $Pr^{-2/3}$ in going from cylinders to spheres. This type of calculation is carried out in Figs. 26–28 for a sphere for both laminar and turbulent flow—i.e., using Eqs. (26) and (27), respectively. The ratios ρ_δ/ρ_∞, μ_δ/μ_∞, as well as β, are computed from Newtonian pressure calculations and isentropic expansion from the stagnation point. Apparently, from Figs. 26–28, the maximum heat transfer would occur at about the 40-deg. angle if turbulence should set in, with the maximum turbulent rate increasing relative to the maximum laminar rate with increasing Reynolds Number.

It should also be pointed out[20] that the turbulent shear stress increases as $x^{(8/5)}$ compared to the laminar increase as x. Thus the shear will also be large at the maximum heating region at about 40-deg. angle. This is important from the aerodynamic-erosion standpoint.

Rough Walls

The above discussion had to do only with smooth walls. When the walls are rough, however, the roughness would have an influence not only on transition but also upon turbulent flow itself. The effect of roughness on transition will be illustrated in the next sections. However, the effect on local turbulent skin friction (and therefore heat transfer) is indicated by the following formula for flat plates:

$$\frac{0.242}{A c_{f_\delta}^{1/2} (T_w/T_\delta)^{1/2}} (\sin^{-1}\alpha + \sin^{-1}\beta) = 1.40 + \log_{10}\left(\frac{x}{\epsilon} \cdot c_{f_\delta}^{1/2}\right) \qquad (28)$$

where ϵ is the plate roughness, and x is the distance from the plate leading edge. It is assumed in the derivation of Eq. (28) that the roughness protuberances are large enough to disrupt the viscous sublayer but not high enough to reach the sonic line. As with skin friction, the heating rates for rough plates should be significantly greater than for smooth plates.

Sweat and Film Cooling

Even if the boundary layer was laminar at the stagnation point, it appears from Figs. 26–28 that the heating rate could still be excessive at extremely high speeds. Sweat or film cooling are means of insulation that are worthy of development. They would be particularly useful to shield the surface in the event of turbulent flow as is also seen in Figs. 26–28. In the latter connection, it should be pointed out that blowing into the boundary layer is a destabilizing agent and therefore should be applied with this in mind.

Boundary-Layer Control and Transition

Now that the extreme cases of laminar and turbulent heat transfer have been discussed with some detail, it is

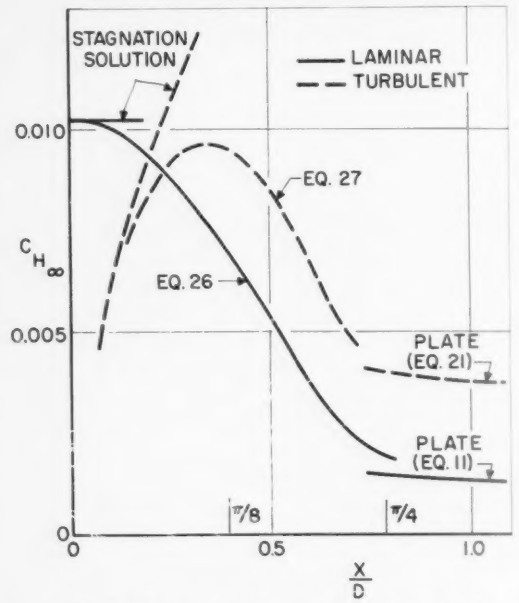

FIG. 26. Heat transfer on the face of a sphere in air ($M_\infty = 3$ and $Re_{D_\infty} = 10^6$).

necessary to examine the important problem of whether or not a boundary layer will be laminar or turbulent. This is the problem of transition. The answer to this question could make or break an overall high-speed-aircraft design because the aerodynamic heating rates for turbulent flow can be 5 to 10 times greater than for laminar flow. While transition is important to the design of such systems as the cruising winged supersonic aircraft, it is critical to the design of the hypersonic glide and ballistic rockets.

It is definitely known that low-speed laminar boundary layers with constant external velocity (pressure) are unstable at relatively low Reynolds Numbers of the order of 100,000 and that turbulence usually sets in at a Reynolds Number of about 3,000,000. High-speed boundary layers on insulated surfaces—i.e., no heat transfer—do not fair much better. However, falling external pressure is a good stabilizing agent for high-speed as well as low-speed flows, as in the case of the laminar flow airfoil which was purposely designed to delay transition by increasing the percentage of chord over which the pressure could fall. In fact, the word "favorable" has been applied to negative pressure gradients along the flow because such gradients tend to hold the boundary layer stable. Ordinarily the pressure gradients on high-speed aircraft wings and bodies are small owing to the flat or slender shapes necessary to decrease wave drag. However, at the noses of bodies and at the leading edges of wings where the heat-transfer rates are expected to be greatest, such as for glide and ballistic-type missiles, the falling pressure will be most welcome. The falling pressure works toward stabilization by filling out the velocity profile—i.e., by increasing the velocity near the surface so that the fluid cannot fold over on itself so easily.

Stabilization by Cooling

Another effective method of boundary-layer control is to cool the laminar boundary layer at the surface. This process is automatic under transient conditions of ascent (boosting) or descent (re-entry). However, for cruising aircraft, some forced method of heat absorption, such as by fuel circulation within the aircraft, must be resorted to. Cooling promotes stabilization by filling out both the density and velocity profiles—i.e., increasing the momentum nearer the surface so that, as with the falling pressure gradient, the fluid cannot fold over on itself so readily. Of course, the opposite effect of encouraging transition would result from heating or from an adverse (positive) pressure gradient.

Theoretical estimates can be made of the cooling rate required to stabilize laminar boundary layers at supersonic speeds. As with incompressible flow where Rayleigh and Tollmien showed that a criterion for instability was that the velocity profile have a reversal—i.e., $\partial^2 u/\partial y^2 = 0$ anywhere in the boundary layer—the criterion for compressible flow[18, 19] is that the gradient of the angular momentum be zero somewhere in the outer part of the layer where

$$\frac{u}{u_\delta} \geqq 1 - \frac{1}{M_\delta}$$

i.e.,
$$\frac{\partial}{\partial y}\left(\rho \frac{\partial u}{\partial y}\right)_{u/u_\delta \geqq 1-1/M_\delta} = 0$$

This is the so-called inviscid solution which is arrived at upon consideration of only the inertial and pressure forces to the neglect of the viscous forces. For the incompressible case with constant external velocity (the Blasius case), the boundary layer is always in impending instability, according to the inviscid solution, because at the wall the curvature of the velocity profile is always zero. For incompressible flow near the stagnation point, where the pressure is favorable, the inviscid criterion indicates stability. For supersonic flow with constant external velocity, the inviscid criterion indicates instability when the flow is insulated—that is, when there is no heat transfer. It is then found that, as the boundary layer is cooled, the layer becomes more and more stable until at a given heat-transfer rate the boundary layer is completely stable. The wall-to-free-stream temperature ratio below which complete stability is possible is shown in Fig. 29. In that Figure, three sets of curves are drawn, depending upon the Prandtl Number and viscosity law (which determine the shape of the density and velocity profiles) prevailing under the condition of motion chosen.[20] It is seen that a limiting Mach Number occurs in each case. A more exact (and complicated) analysis can be carried out which takes into consideration the viscous forces. For incompressible flow with any external pressure variation, it is found that inclusion of the viscous forces in the analysis predicts stability at sufficiently low Reynolds Number so that there is a minimum critical Reynolds Number below which all disturbances damp out. Thus, a Blasius layer can really be either stable or unstable, depending upon the speed—that is, it is not always in a condition of neutral

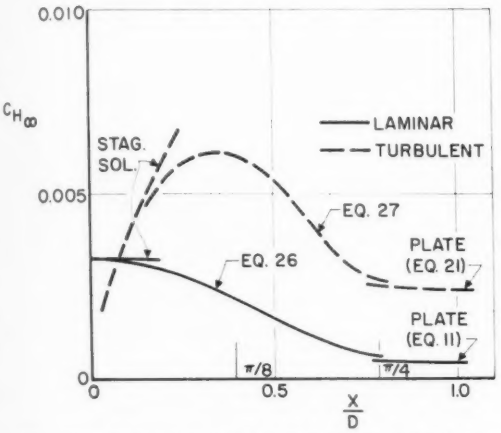

FIG. 27. Heat transfer on the face of a sphere in air ($M_\infty = 3$ and $Re_{D_\infty} = 10^6$).

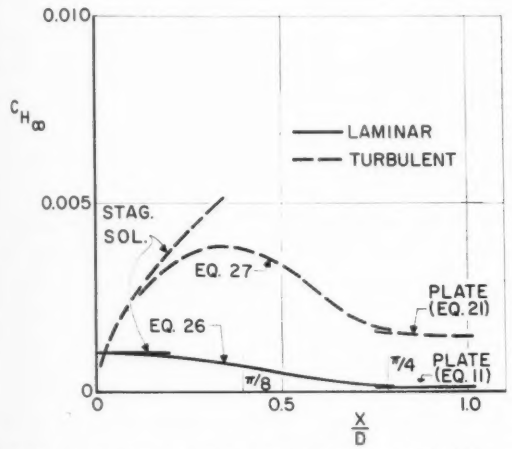

FIG. 28. Heat transfer on the face of a sphere in air ($M_\infty = 3$ and $Re_{D_\infty} = 10^7$).

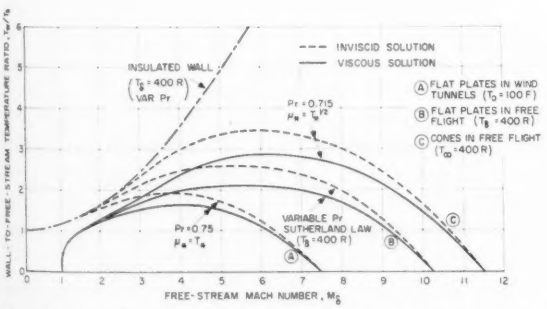
WALL-TO-FREE-STREAM TEMPERATURE RATIO, T_w/T_∞
FREE-STREAM MACH NUMBER, M_∞
INVISCID SOLUTION
VISCOUS SOLUTION
INSULATED WALL (T_∞ = 400 R) VAR Pr
Pr = 0.715 $\mu_w = T_w^{1/2}$
Pr = 0.75 $\mu_w = T_w$
VARIABLE Pr SUTHERLAND LAW (T_∞ = 400 R)
A FLAT PLATES IN WIND TUNNELS (T_0 = 100 F)
B FLAT PLATES IN FREE FLIGHT (T_∞ = 400 R)
C CONES IN FREE FLIGHT (T_∞ = 400 R)

FIG. 29. Cooling required for complete stabilization of the laminar boundary layer for air.

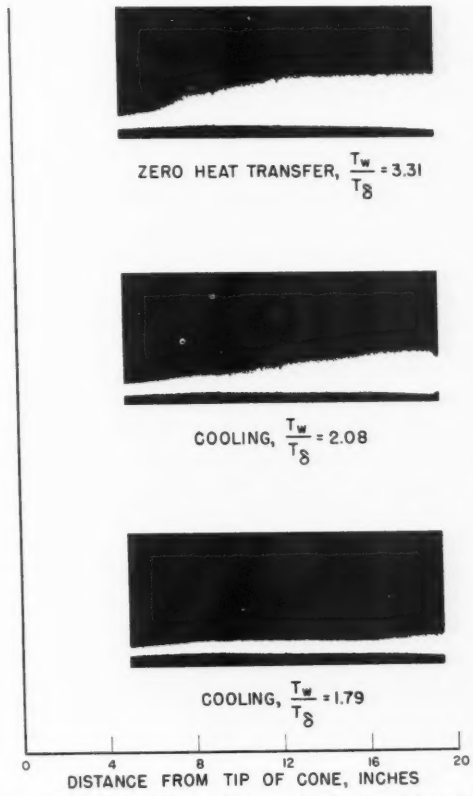

FIG. 30. Magnified schlieren photographs showing delay of transition by surface cooling ($M_\delta = 3.65$ and $Re_\delta/\text{inch} = 0.50 \cdot 10^6$).

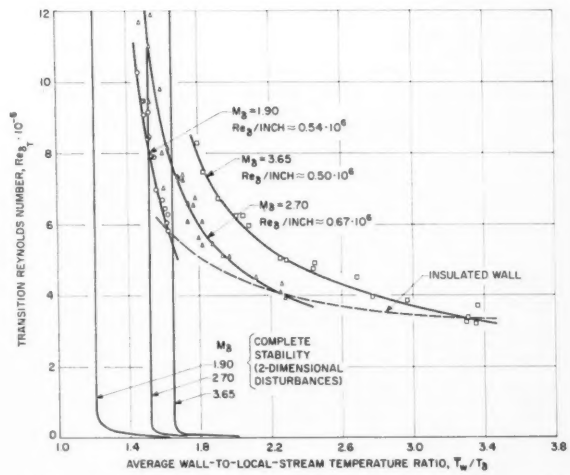
TRANSITION REYNOLDS NUMBER, $Re_{\delta_T} \cdot 10^{-6}$
AVERAGE WALL-TO-LOCAL-STREAM TEMPERATURE RATIO, $\bar{T}_w/T_\delta$
M_δ = 1.90 Re_δ/INCH = 0.54·10⁶
M_δ = 3.65 Re_δ/INCH = 0.50·10⁶
M_δ = 2.70 Re_δ/INCH = 0.67·10⁶
INSULATED WALL
M_δ 1.90 2.70 3.65 COMPLETE STABILITY (2-DIMENSIONAL DISTURBANCES)

FIG. 31. Effect of surface cooling on transition Reynolds Number for several local Mach Numbers on a smooth 10-deg. cone (0.4 per cent supply turbulence).

stability as indicated by the inviscid solution. In spite of a favorable pressure gradient such as near the stagnation point, a boundary layer is expected to be unstable at a sufficiently high Reynolds Number—although at a greater Reynolds Number than for a Blasius layer owing to the added stabilizing effect of the falling pressure. Finally, for compressible flow, the inclusion of the viscous effects requires a greater cooling rate to stabilize the flow. In fact, it is only in supersonic flow that the boundary layer can be completely stabilized. The viscous solution for two-dimensional disturbances[20] is also shown in Fig. 29.

It is important to notice in Fig. 29 that the cooling rates required to stabilize completely the boundary layer are within practical reach, certainly under transient conditions during which the wall-to-free-stream temperature ratio remains low. Boosting trajectories should penetrate the stability loop from the left, whereas re-entry trajectories should enter it from the right.

Experiments have verified the theoretical prediction that cooling the boundary layer delays transition. In a current research program[21] conducted by North American Aviation, a 20-in., 10-deg.-apex-angle cone is cooled internally by precooling gaseous nitrogen so that temperature ratios well below the stability loops of Fig. 29 are obtained. Transition is then observed by means of magnified schlieren technique. Fig. 30 shows photographs of the boundary layer magnified 20 times normal to the flow. The testing was carried out at the Jet Propulsion Laboratory 12-in. Wind Tunnel. The local Mach Number was 3.65, and the Reynolds Number per inch was $0.50 \cdot 10^6$. The top picture shows transition with no cooling; the next two show the successive delay of transition with increasing cooling. Fig. 31 gives transition data obtained from such photographs for local Mach Numbers 1.90, 2.70, and 3.56. In Figs. 30 and 31 the cone was smooth and the turbulence was low.

Figs. 30 and 31 indicate that transition can be delayed by cooling when the surface is smooth and the tunnel turbulence low. However, for engineering purposes, it is necessary to determine whether transition can still be delayed by cooling in the presence of surface roughness and free-stream turbulence. Although the answer to this question is now classified, it can at least be said that the effects of both roughness and turbulence in promoting transition decreases as the Mach Number increases. This is well observed in Figs. 32 and 33 where the ratio of the actual transition Reynolds Number $Re_{\delta T}$ to the smooth-body low supply-chamber turbulence (0.4 per cent) Reynolds Number Re_{δ_0} is plotted vs. intensity of turbulence in the tunnel supply chamber $(u'/u)_0$ and relative roughness (wire height k to displacement thickness δ_k^*), respectively. Only the data for zero heat transfer are shown. The wires were set at 3 in. from the cone vertex. Also shown in Fig. 33 is the low-speed correlation developed by Dryden.[22]

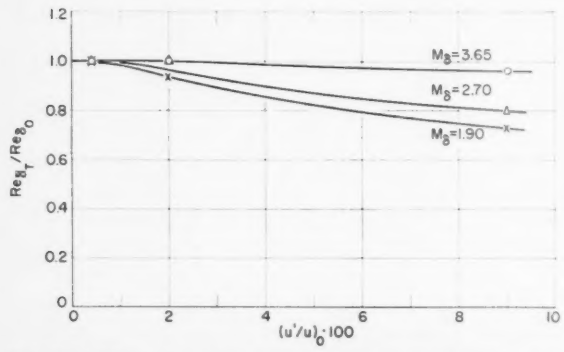

FIG. 32. Effect of supply-stream turbulence on transition as a function of Mach Number (zero heat transfer).

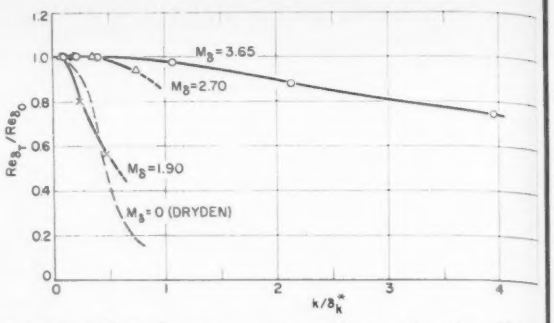

FIG. 33. Effect of roughness on transition as a function of Mach Number (zero heat transfer).

Free-flight data obtained by Fischer and Norris,[23] Sternberg,[24] and Snodgrass[25] also seem to support the theory for smooth surfaces.

EFFECT ON PERFORMANCE AND DESIGN OF WINGED HIGH-SPEED AIRCRAFT

The delay of boundary-layer transition not only decreases the aerodynamic-heating rates considerably but also increases the performance of winged high-speed air vehicles. It is spectacular how many benefits accrue. Aside from the myriad of high-temperature problems (such as with fuel, oil, rubber, electronics) that are alleviated, the structural weights will decrease, and perhaps even stiffer structures could be used. And, of course, for a given range and speed, the quantity of fuel would be less. There would, however, be plumbing problems because undoubtedly the fuel or coolant would have to be circulated within the missile and perhaps through annular surface structure.

An example of the effect of delay of transition on performance is easily calculated. A futuristic commercial air liner designed to fly from coast to coast (say 3,000 miles) at a supersonic Mach Number of perhaps 3 could very well have a zero-lift drag coefficient composed of 50 per cent pressure drag and 50 per cent turbulent friction drag. If the boundary layer could be stabilized by cooling such that considerable laminar flow prevailed over the airplane surface, the skin-friction drag might be reduced by as much as 50 per cent, which would reduce the C_{D_0} by 25 per cent. If other factors remain constant, the range of the airplane would vary proportionally to the square root of the ratio of C_{D_0} with turbulent flow to that with laminar flow. In this illustration, the range would increase about 15 per cent—or 450 miles on the assumed transcontinental flight.

Areas of Future Research

In looking over the vast amount of recent effort to understand the mechanism of aerodynamic heating, one quickly concludes that, although many advances have been made, there is still a lot to be learned before the engineer can be confident in his design. Most of the available knowledge concerns the extreme cases of laminar and turbulent flows with zero or linear pressure gradients. Also, some understanding is evident in the control of transition. Certain areas of research in aerodynamic heating which must be explored further are:

(1) Effects of surface roughness and free-stream turbulence on the control of transition by cooling at supersonic flow for flat plates with cylindrical leading edges and for cones with spherical noses.

(2) Study of (1) for hypersonic flow with realistic temperature behind the bow wave.

(3) More definite data on turbulent heat transfer on flat plates.

(4) Effect of roughness on turbulent heat transfer at ordinary supersonic flow.

(5) Stability of boundary layers near the stagnation point.

(6) Viscous flow solution at leading edges of plates and points of cones.

(7) Heat transfer in separation areas such as before control surfaces and in wakes.

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Lift on a Wing in a Propeller Slipstream as Related to Low-Speed Flight

An analytical solution in parametric form of the lift on a fixed wing extending through a propeller slipstream, which is valid for all slipstream-velocity/forward-flight-velocity ratios, has been obtained, permitting the employment of optimization techniques which should appreciably advance our attack on the problems of low-speed flight.

Introduction

General Problem of Low-Speed Flight

A requirement for vertical take-off and landing has existed since the days of the Wright brothers. This requirement in recent years has received more emphasis because of the pressure toward dispersal caused by nuclear weapons. Also, the availability of turboprop engines of high power-to-weight ratios has broadened the areas of endeavor in which vertical operations are feasible.

In most fields of endeavor, we learn to walk before we run. In the field of flight, however, we have gone at the problem the other way. We learned to go quite fast before we learned how to stand still.

Of course, the operational use of an airplane is much greater when it is going some place fast rather than standing still. Aside from this operational emphasis, however, there are major technical problems and limitations on flight at the lower end of the speed range.

Chief among these is the basic problem of providing sufficient lift at low speeds. The lift which sustains an airplane in flight is derived from the downward momentum imparted to the mass of air affected by the airplane. This lift varies with the mass of air affected and with the first power of the downwash velocity imparted to it. The kinetic energy expended to produce this lift, however, also varies with the mass of air affected—but with the square of the downwash velocity imparted to it. Hence, it is more efficient to obtain the required lift by imparting a small downward velocity to a large mass of air than to impart a large downward velocity to a smaller mass of air.

The mass of air affected by the wing is, of course, proportional to the flight speed and so, in conventional fixed-wing configurations at zero forward speed, becomes vanishingly small. Hence, the problem fundamentally is one of providing an aerodynamic means to involve a large mass of air to which sufficient downward velocity is imparted to provide the required lift at low flight speeds.

Fixed-Wing Configurations

Operational Considerations—There are many reasons to approach the low-speed flight problem from the standpoint of reasonable modifications of conventional propeller-driven fixed-wing aircraft. Among these reasons are the obvious merits of retaining all the present desirable and highly developed characteristics of present conventional fixed-wing aircraft, such as efficiency and good flying qualities. Also, considerations of passenger comfort and cargo loading require that the fuselage be kept more or less horizontal at all times, which is an inherent characteristic of such conventional configurations. Furthermore, the greatest share by far of our experience and proved capabilities lies in the field of propeller-driven fixed-wing aircraft.

It is also useful to take the point of view that a vertical take-off and landing capability is but the ultimate limit of a short take-off and landing characteristic.

From these standpoints, it would seem prudent to work steadily toward this low-speed goal from the extensive foundation already in hand in conventional propeller-driven fixed-wing aircraft. Thus it appears reasonable to strive steadily toward the ultimate VTOL goal, taking advantage in the meantime of the not inconsiderable advantages of STOL characteristics. In fact, different requirements will, in the end, tilt the inevitable aircraft design compromise toward VTOL for certain applications and STOL for others. In line

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with this reasoning, we will hereafter speak only of STOL aircraft, which is then understood to include VTOL as a special case.

The feasibility of this approach is by now well justified by the many preliminary studies which indicate that this goal may eventually be attained in a practical manner by such an extension of propeller-driven fixed-wing aircraft. The question now is how best to proceed to reach this goal most effectively and efficiently.

Technical Considerations—The lift obtained from a fixed wing immersed in a propeller slipstream at zero forward speed is essentially due to the rotation of the propeller thrust vector. The lift obtained at finite low forward speeds is a more complex interaction of the wing flow and the superimposed propeller flow. The primary aerodynamic question is then one of determining the basic rules which govern both the magnitude and distribution of this lift as a function of both the slipstream velocity ratio and the geometry of the wing-propeller arrangement. Once these rules are determined, preliminary design can readily evoke the optimum STOL characteristics compatible with other considerations.

The important related problem of stability is, of course, solved at the same time with knowledge of where the lift acts.

Discussion

Present State of Knowledge

In order to conduct an effective and efficient attack on this problem, it is essential to know how the lift on a wing in a propeller slipstream varies as a function of the many design variables involved. This is the standard engineering approach that we use every day in the normal course of our work.

At present, however, there is no theory which predicts the lift obtained by a wing in a propeller slipstream which is adequate for STOL configurations. An analytical treatment of this problem was given many years ago by Koning[1] based on lifting-line theory. The results of Koning's analysis, because of his method of computation, are valid only for small increments of the slipstream velocity. Other early estimates[2–4] were based on semiempirical factors and gave satisfactory results within the speed-power range for which they were developed. However, the higher ratios of slipstream velocities now available through more powerful engines in STOL configurations require solutions valid at all slipstream velocities. The problem is no longer one of small influences due to the slipstream, for in STOL configurations the slipstream velocity dominates the aircraft characteristics at low flight speeds.

More recently, Graham, Lagerstrom, Licher, and Beane[5] conducted a study of this problem for Douglas Aircraft Co., Inc., carrying out the computations derived by Koning's lifting-line theory by more exact machine methods than were available in Koning's time. Graham also derived an independent solution to the problem based on slender-body theory.

Unfortunately, there is a dearth of experimental data in the literature on wings in a propeller slipstream with which to compare these theories. However, there was one experimental program, conducted by Stuper[6] in Germany in 1938, which carefully measured the lift distribution for a wing extending through a propeller slipstream, and his experimental results have been used by those working in this field for comparison with theory. Stuper's experimental results lie between the predictions given by Koning's lifting-line theory and Graham's slender-body theory, and the differences are large.

In most cases of interest, the width of a propeller slipstream is of the same order as the chord of the wing immersed in it. With the aspect ratio of the immersed segment thus of the order of one, it would seem that lifting-surface theory would be required to describe properly the actual conditions. The fact that the available experimental data lie midway between the two limiting theories, lifting-line and slender-body, would appear to support this view.

Dominate Effect of Geometry on Lift

It is obvious that effective and efficient design of fixed-wing STOL aircraft requires a thorough knowledge of the magnitude and distribution of the lift on the wing immersed in the propeller slipstream and a complete picture of how that lift varies as a function of the many design parameters involved.

As has been pointed out, at zero forward speed the mechanism of lift of a wing immersed in a propeller slipstream is essentially one of rotation of the thrust vector. It would be expected that lift would appear only on that portion of the wing within the slipstream diameter. Hence, if VTOL characteristics alone were dominating, the propellers should have the largest diameter possible and the wing geometry should be such that the entire wing is immersed in the propeller slipstream.

At finite low forward speeds the mechanism of lift of a wing immersed in a propeller slipstream is a more complex interaction of the wing flow and the superimposed propeller flow. The lift on that portion of the wing within the slipstream is appreciably less than that corresponding to an infinite flow field of the slipstream velocity. The lift on that portion of the wing outside the slipstream is appreciably greater than that corresponding to an infinite flow field of the flight velocity. These differences between the actual lift and that indicated by the local velocity are large. Also, the appreciable lift increment on that portion of the wing outside the slipstream extends outboard for several slipstream diameters.

Thus, at finite low forward speeds there occurs an appreciable redistribution of the lift across the span. In particular, that portion of the wing beyond the slipstream boundary carries a large portion of the lift increment due to the slipstream.

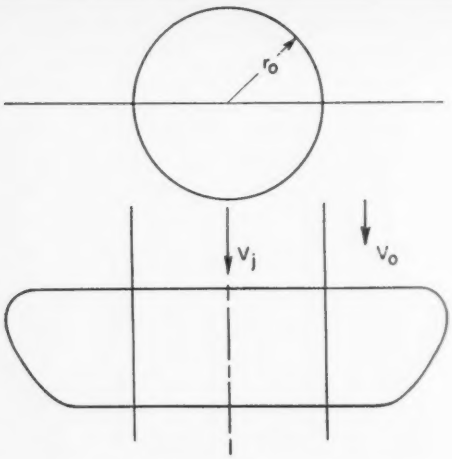

FIG. 1. Airfoil spanning a circular jet.

The importance of knowing both the magnitude of the lift and its distribution across the span is obvious. Such knowledge is required from many standpoints, among which are structural, performance, and control considerations.

It is suspected that the magnitude of the lift of a slipstream-immersed wing may be determined uniquely by only certain of the parameters—say the propeller parameters and the wing area—while other parameters, such as the wing aspect ratio, may influence only the distribution of the lift and not its magnitude. However, any such hypothesis has yet to be established. If such were the case, compatibility between STOL characteristics and efficient cruise characteristics would be enhanced.

In any event, it is clear that knowledge of both the magnitude and distribution of the lift as a function of slipstream velocity ratio and of all parameters involving the wing-slipstream geometry is an essential part of the basic knowledge required for an effective attack on the problems of low-speed flight.

Analytical Solution

An analytical solution of this problem has been obtained. This solution is based on lifting-surface theory. The results obtained from it show good agreement with experiment.

The mathematical analysis of this analytical solution[7] is being submitted to the JOURNAL OF THE AERONAUTICAL SCIENCES for publication. This complete analysis will include a detailed description of how the method may be applied to design. Accordingly, it is proposed here to present only a brief outline of the method of attack and then to illustrate in a general manner how the results can be employed in design.

Basic Principles

The fundamental problem to be solved, as illustrated in Fig. 1, is an airfoil spanning a circular jet. This physical model thus consists of a circular jet of velocity V_j bounded by an infinite outer flow of velocity V_o. The finite wing symmetrically extends completely across the jet into the outer flow on both sides.

In the analysis, the airfoil was replaced by a series of finite horseshoe vortices. The case for such a vortex inside or outside of the jet was then solved separately. These horseshoe vortices, illustrated in Fig. 2, were represented in width parametrically so that combinations could later be superimposed to represent any arbitrary wing-jet combination, such as is illustrated in Fig. 3.

The boundary of the jet is a free surface. The presence of differing velocities on its two sides gives rise to a vortex sheet on the boundary. This vortex sheet has associated with it a flow system such that the required conditions on pressure and continuity of the boundary are satisfied.

Thus the requirements of the jet boundary determine the flow, aside from the singularities represented by the wing and its wake. Two conditions must be satisfied on the boundary. In a linearized small perturbation theory, these are:

(1) The pressure of the inside flow (region j) must, at the boundary, equal the pressure of the outside flow (region o). Otherwise, the acceleration of the fluid would be infinite across the boundary. In terms of the perturbation velocity $\boldsymbol{v}$, whose axial and radial components are u and u_r, respectively, this condition is written

$$V_j u_j = V_o u_o \tag{1}$$

(2) This boundary condition is one of continuity and states that the boundary must consist of streamlines—that is, the inside and outside flow must be tangent at the boundary. For a circular jet, this tangency condition is expressed as

$$V_o u_{r_j} = V_j u_{r_o} \tag{2}$$

The perturbation flow $\boldsymbol{v}$ is composed of two parts—that due to the wing and that due to the boundary. The flow due to the wing, or to the system of horseshoe vortices used to represent it, is known and may be readily determined by the Biot Savart law. The essential problem, then, is to determine the flow due to

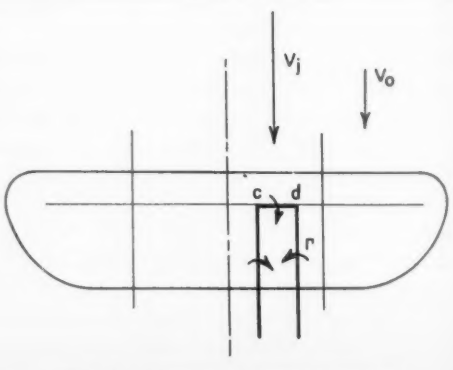

FIG. 2. Elementary horseshoe vortex.

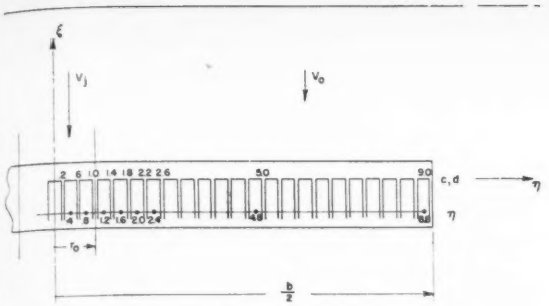

FIG. 3. Arrangement of wing-jet vortex pattern (with notation used to determine jet boundary downwash coefficients).

the jet boundary. The sum of the two flows then constitutes the total perturbation flow.

We note that the single elementary horseshoe vortex of strength Γ may be decomposed into two halves, one even (1) and one odd (2), each of strength Γ/2, as illustrated in Fig. 4. These two systems are independent and satisfy the boundary conditions independently.

The physical significance of this decomposition of a horseshoe vortex into its even and odd parts with respect to the flow direction is quite clear. The even part is even in the sense that the downwash produced by it is the same in magnitude and direction at equal distances fore and aft of the lifting line. In fact, in this particular case, this downwash is constant with respect to the flow direction—that is, it is two dimensional—and it is this two-dimensional feature that makes the analysis of the even part quite simple, permitting the employment of the well-known image techniques.

The odd part is odd in the sense that the downwash produced by it is the same in magnitude but opposite in direction at equal distances fore and aft of the lifting line. This component of the downwash is not constant with respect to the flow direction and so is three dimensional, involving a more complex analysis which is nevertheless facilitated by the antisymmetry property described above.

This decomposition of the vortex into its even and odd parts with respect to the flow direction thus facilitates the solution of the problem. It should be noted that the odd part, being antisymmetric about the lifting line, of course, vanishes there. Hence, at the lifting line itself, the only contribution is that of the more easily determined even part. Thus, if the wing segment in the jet could be adequately represented by a lifting line, the odd part could be disregarded. This simplification of the problem was the basis of the earlier solution by Koning[1] which is valid only to the degree that the segment of the wing in the jet may be approximated by a lifting line.

As was pointed out earlier, however, in most cases of interest for practical applications the aspect ratio of the wing segment immersed in a propeller slipstream is of the order of one, for which a lifting line is a very poor approximation. Hence, to obtain a valid representation of the flow, the downwash at points aft of the lifting line must be determined, and this can be done only by obtaining a solution to the odd part as well.

The present analysis therefore includes a determination of the downwash due to both the even and odd parts of the horseshoe vortex. This derivation thus essentially determines the downwash anywhere in space due to the vortex sheet constituting the boundary of a slipstream through which there extends a wing. The physical nature of this problem was straightforward; the only difficulty lay in the mathematics of the three-dimensional odd part.

Method of Analysis

Briefly, the mathematical difficulty lay in the fact that the usual representation of the known perturbation flow of the horseshoe vortices used to represent the wing by the scalar form of the Biot Savart law leads to elliptic integrals which, because of further operations required, makes the analysis unwieldy. This difficulty was circumvented in the present analysis by using a vector form of the Biot Savart law which in turn permitted the use of convenient addition formulas that separated the variables, thereby achieving a representation of the known perturbation flow due to the wing in a form identical in several respects with that of the unknown perturbation flow due to the jet boundary. This similarity in form circumvented

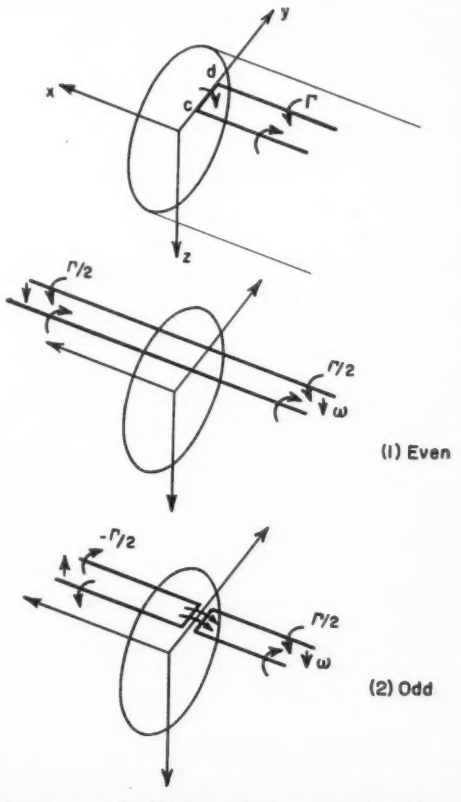

FIG. 4. Even and odd parts of elementary horseshoe vortex inside jet.

further integrations and otherwise simplified the analysis.

Assumptions Involved

The above physical model, which was used as the basis for the solution described, necessarily contains several idealizations of the actual flow which were necessary in order to make the problem amenable to analytical treatment. The three principal assumptions were:

(1) No rotation of the propeller flow. Such rotation in effect produces a change in the local effective angle of attack, which may require a final correction to the angle of attack for which the lift was predicted.

(2) The velocity increment in the jet is a step function. The actual velocity, of course, varies across the jet although these variations should tend to equalize themselves downstream.

(3) Linearized wing theory. This assumes that the perturbations in the flow due to the wing are small as compared to the uniform flow field.

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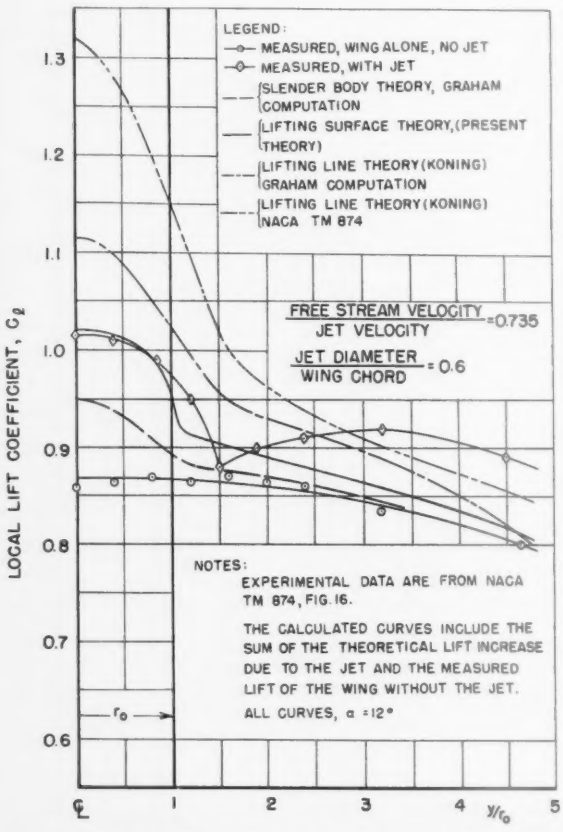

FIG. 5. Comparison of various theories with experiment for spanwise lift distribution of wing extending through circular jet.

Vortex Inside Jet:

$$G_{jj}{}_{odd}(\xi,\eta) = \frac{8}{5\pi\eta}\sum_{p=0}^{\infty}(2p+1)^2\int_0^{\infty}\frac{KK'I(\eta\lambda)\sin\xi\lambda\,d\lambda}{\frac{1}{\left\{\frac{1}{\mu^2}-1\right\}}-\lambda IK'}\int_{c\lambda}^{d\lambda}\frac{I(\lambda\beta)}{\lambda\beta}\,d(\lambda\beta)$$

$$G_{oj}{}_{odd}(\xi,\eta) = \frac{8}{5\pi\eta}\sum_{p=0}^{\infty}(2p+1)^2\int_0^{\infty}\left[\frac{1}{\mu-\lambda\left\{\frac{1}{\mu}-\mu\right\}IK'}-1\right]\frac{K(\eta\lambda)\sin\xi\lambda\,d\lambda}{\lambda}\int_{c\lambda}^{d\lambda}\frac{I(\lambda\beta)}{\lambda\beta}d(\lambda\beta)$$

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FIG. 6. Jet boundary downwash coefficients, odd system. *Note:* All Bessel functions are of $2p+1$ order and, unless otherwise shown, are of argument λ.

RESULTS

The initial results of the present analysis are values of downwash at all points in space due to the jet boundary. These values of downwash may then be inserted into a suitable lifting-surface theory, such as that of Weissinger,[8] to obtain the final results which are magnitude and distribution of lift.

Initial Results—Jet Boundary Downwash Coefficients

The solution for the downwash coefficients was carried out in parametric form so that the expressions obtained may be used to determine the characteristics of any wing-jet geometry at any jet velocity ratio. The expressions obtained appear as sums of infinite integrals. Fig. 6 illustrates these integral expressions for the downwash due to the odd part in coefficient form. Fig. 7 illustrates the algebraic expressions for the coefficients of the downwash due to the even part obtained from two-dimensional theory, which the odd expressions approach asymptotically at large distances from the lifting line of the wing. Fig. 8 contains a list of the notation used in these expressions.

These expressions have been programmed for computation by IBM Type 701 Electronic Data Processing Equipment. The computations have been carried out for one test case, and it is proposed to complete these computations for all values of the geometrical and jet velocity ratio parameters of interest in a set of tables for general use. In the meantime, it is a simple matter to carry out the computations for any wing-jet combination at any particular jet velocity ratio by simply inserting the necessary values of the parameters into the IBM computer with the existing program.

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$$G_{jj_{even}}(\eta) = \frac{1}{5}\frac{1-\mu^2}{1+\mu^2}\left[\frac{1}{\frac{1}{d}-\eta}-\frac{1}{\frac{1}{c}-\eta}+\frac{1}{\frac{1}{d}+\eta}-\frac{1}{\frac{1}{c}+\eta}\right]$$

$$G_{oj_{even}}(\eta) = -\frac{1}{5}\frac{(1-\mu)^2}{1+\mu^2}\left[\frac{1}{\eta-c}-\frac{1}{\eta-d}+\frac{1}{\eta+d}-\frac{1}{\eta+c}\right]$$

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cation of the theoretical analysis of the problem, the IBM results for the downwash were employed in Weissinger's lifting-surface method[8] for comparison with the available experimental data of Stuper.

Final Results—Magnitude and Distribution of Lift

The comparison of the theory with Stuper's experiment[6] is shown in Fig. 5. This figure also includes the other theories mentioned previously.

Inside the jet, which is the region of greatest effect and hence of principal interest, this figure shows good agreement between the present theory and the experimental data of Stuper.

Outside the jet, there are two points to note regarding the experimental data. (1) Immediately beyond the jet boundary, a strong decrease in lift is observed, which is explained by Stuper as being due to the friction boundary layer of the fan enclosure. (2) Further beyond the jet boundary, a large increase in lift is observed, which may be explained by the shroud over the fan extending two chord lengths upstream and providing a solid boundary which is not present either in the theory or in practice.

The lift predicted outside the jet by the present theory, on the other hand, appears reasonable, as it lies between the two limiting theories—lifting-line and slender-body—in much the same manner as inside the jet. Furthermore, it asymptotically dies out going outboard from the jet, which appears reasonable physically.

Fig. 5 also illustrates the general redistribution of the lift indicated earlier in this paper. The lift increment in the jet is less than half of the value based on the local jet to free-stream velocity ratio. Yet the lift increment outside of the jet is appreciable for many jet radii outboard.

It should be emphasized here that this test case is at a fairly low velocity ratio—namely, 1.36—and that the lift increment is not very large. It would not be unreasonable to expect jet velocity ratios of the order of 2 to 5 at take-off speed for STOL configurations, and, of course, for VTOL the ratio is infinite. Hence, the low lift increments illustrated in the test case are not to be considered as representative in magnitude of those contemplated for low-speed flight; they were used in this test case simply to permit comparison with the only experimental data available in the literature.

APPLICATION TO DESIGN

The present analytical solution should be considered as an initial basic step in the theoretical attack on this problem. This work is highly successful in that it produces results showing the dependence of the lift on the primary variables of slipstream velocity ratio and wing-slipstream geometry.

The results described in this paper may be applied to design at the present time. The initial results—the jet boundary downwash coefficients—which are presented in Figs. 6 and 7 and which are already programmed for IBM Type 701 equipment, will provide the values of downwash anywhere in space due to a given wing-slipstream configuration at all jet velocity ratios. These values may then be used with any lifting-surface theory, such as that of Weissinger, to determine both the magnitude and distribution of the lift for the configuration as a function of the slipstream to free-stream velocity ratio. This application is of value on configurations already frozen as a check on the structural, performance, and control analyses already made by other methods or assumptions.

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FIG. 8. Notation.

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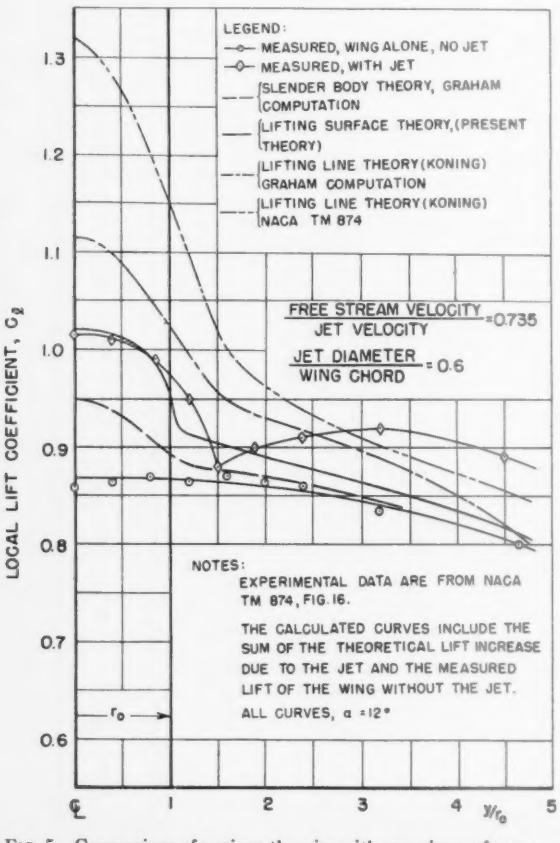

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FIG. 8. Notation.

of tail surfaces and may thus contribute toward the handling of the critical stability and control problems in STOL configurations.

Three main assumptions employed in the development of the present theory have been pointed out and briefly discussed. Although these are idealizations not actually realized in practice, their effects are in general felt to be secondary, and their use permits the achievement of a solution illustrating the primary effects. Nevertheless, in application to design, as with any theory, allowance must be made for these secondary effects, and, where possible, the values indicated by the theory should be checked by experiment.

The chief value of theory in design is that it substitutes for the lack of any experimental data and indicates how to modify existing data for one configuration to a new configuration.

An even more useful result of the present theory, however, and perhaps its chief contribution, is its utility in the selection of optimum configurations. The results described above can be applied at this time to a family of configurations in the neighborhood of a proposed arrangement. Design charts illustrating the trends of the magnitude and distribution of lift as a function of the parameters varied could then be prepared and their effects determined. This method is thus highly useful in the selection of optimum configurations.

A more powerful optimization method, however, would be to employ calculus of variations techniques to maximize the lift per unit wing area and per unit power. This work has not yet been carried out but should be feasible now that an analytical solution of the lift problem has been obtained.

It is contemplated that, if such a maximation program could be accomplished, the results could be presented in the form of curves showing the variations of lift with each parameter, and thereby the individual contributions to the lift could be isolated and the maximum points obtained more readily.

Conclusions

This paper has presented a theory for the characteristics of a wing extending through a propeller slipstream. The theory presented goes beyond previous theories in that it is based on lifting-surface considerations and employs a method of analysis that is valid at all jet velocity ratios. Thus, the formulation is representative of the actual STOL problem, and the results obtained from it are shown to agree well with the experimental data. Hence the theory is felt to be adequate for design purposes.

The theory predicts both the magnitude and distribution of lift for any arbitrary combination of wing-slipstream geometry and at all ratios of the slipstream velocity to forward-flight velocity.

The results are in a parametric form which is useful for design purposes at the present time and which is particularly useful for optimization of configurations as a function of general design parameters, such as wing loading and power loading.

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Economics of Rocket-Propelled Airplanes—Part II*

(IV) Direct Flying Cost of Rocket Aircraft (*Continued*)

(D) *Depreciation Costs*

The portion of the direct flying cost which is contributed by depreciation allowance may be computed in a manner similar to that used to compute the interest charges. Assume that the rocket airplane has a service life of 10,000 hours, and, as in the previous case, that the average cost of structural elements is 6,000 cents/lb. The depreciation cost, cents per pound of structure per hour of service life, is then

$$6{,}000/10{,}000 = 0.6 \text{ cent/lb. of structure/hour of service life}$$

It may be immediately concluded that the depreciation costs (0.6 cent/lb./hour) are five times the interest costs (0.12 cent/lb./hour). This ratio, 5/1, is fixed by the assumed interest rate, the assumed service life, and the assumed annual use (3,000 hours). Since these assumed numbers are fairly typical of contemporary airline practice, it may be concluded that, in general, the depreciation costs are large compared to the interest costs. The interest costs are often ignored—or lumped with depreciation.

(E) *Maintenance*

Maintenance, repairs, and ground handling costs in most contemporary air lines vary from 100 to 150 per cent of the depreciation costs, depending on the type of airplane and other factors. A rate of 150 per cent was used in the study.

(F) *Labor Costs—Flight Personnel*

Since dead weight is at such a premium, it is probable that the number of crew members used on rocket aircraft will be kept to an absolute minimum. Assume for the moment that each airplane has a crew of two members, each of whom is paid at the rate of $100 per hour. Assume further that the average flight speed is 6,000 m.p.h., and the pay load is 10 tons. The labor cost is then only 1/3 cent/ton-mile. Since this cost is undoubtedly small compared with the other direct flying costs, it is highly possible that the pilots would be successful in a request for payment at the rate of $100 per hour!

If a pilot is 20 lbs. overweight (=0.01 ton) and revenue is at a rate of 6 cents/ton-mile, the air line is losing revenue at the rate of

$$0.01 \text{ ton} \times 6{,}000 \text{ m.p.h.} \times 0.08 \text{ cent/ton-mile} = \$3.60/\text{hour}$$

On passenger-carrying flights, the rate will probably be several times as large. Thus the selection of a pilot weighing 120 lbs. could easily save the air line as much as $50/hour (per pilot) compared to the employment of a pilot weighing 200 lbs.

In all cases, the salary cost of the flight personnel was assumed to be 0.3 cent/ton-mile.

(G) *Effect of Load Factor*

By "load factor" is meant the ratio of actual pay load carried on a given flight to the maximum or design pay load which might have been carried. Thus, if only 50 seats of a 100-passenger airplane are filled, the load factor is 0.5.

For contemporary airplanes, the *gross* direct flying costs of a given flight are relatively independent of the load factor. This follows from the fact that the only component of the direct flying cost affected by the load factor is the amount of fuel consumed. Even this factor is changed only a few per cent by relatively extreme changes in load factor.

Consider an airplane in which the gross direct flying cost is independent of the load factor, L. The unit direct flying cost, X, in cents per ton-mile, is then given as $X = X_{100}/L$, where X_{100} is the unit cost at unity load factor. Thus, at 0.5 load factor, the unit direct flying costs are doubled.

An extremely different situation exists for the rocket-powered airplane. Here the major component of the gross direct cost of a given flight is the cost of the propellants burned. If the load factor is less than 1.0 on a

* Part I appeared in the September issue of the Review, pp. 30–36, 71.

given flight, the amount of propellant needed to reach the destined objective is reduced. These facts are shown graphically in Fig. 4-6.

(*H*) *Direct Flying Costs*

The value of the nonfuel components, minus labor costs, of the direct flying cost of a rocket airplane may now be tabulated as follows:

Item	Cost (cents/lb. of structure/hour of service life)
Depreciation	0.6
Interest	0.12
Maintenance	0.9
Taxes and insurance	0.1
Total	1.72

To aid in making meaningful comparisons, these costs should be converted to a "cents per ton-mile" basis. This can be done in the following manner:

(1) The "lb. of structure" is converted to "lb. of pay load." Consider a rocket airplane making a 4,250-mile flight with a load factor of 0.8. The ratio between pounds of structure and pounds of pay-load capacity, for the flight conditions specified, can be determined from Fig. 4-5. Column A in Table 4-4 was thus determined. A new curve (corresponding to Fig. 4-5) would have to be plotted for each flight range and each propellant performance.

(2) The "lb. of pay load" must be converted to "ton-miles/hour." If the average flight speed is 5,000 m.p.h., each pound of pay-load capacity can produce 5,000/2,000 = 2.5 ton-miles of transporatation during each hour of service life.

(3) Finally, in order to compute the nonfuel costs (minus labor costs) for the 0.80 load factor specified in the preceding paragraph, a factor of 1/0.8 is used.

To summarize, column B of Table 4-4 is obtained by multiplying the cost of 1.72 cents/lb. of structure/hour of service life, by

(a) Column A (to convert structural weight into pay load).

(b) 2.5 (to convert "lb. of pay load" capacity into "ton-miles/hour" for each pound of pay-load capacity).

(c) 1/0.8 (the pay-load factor).

The total direct flying cost of the rocket-propelled airplane may now be computed. The results are given in Table 4-5. The propellant costs for a load factor of 0.80 are computed in the manner described in Section IV (B), pp. 34–36, 71, of the September issue.

It can be seen that, unless the unit cost of the propellant mixture is greatly reduced, the propellant cost will always be the dominant portion of the total direct flying cost.

(V) Current Freight Rates

In all of the following cases, an attempt was made to determine the rock-bottom shipping costs. Shipping only is quoted; pickup and delivery are extra. All prices were reduced to "cents/ton-mile."

In all available types of public transportation, the transportation cost depends upon the commodity being shipped. There is an understandable tendency to charge what the traffic will bear. For example, most American railroads require the shipper of an embalmed human body to buy first-class Pullman tickets regardless of whether or not anyone uses the seats thus provided.

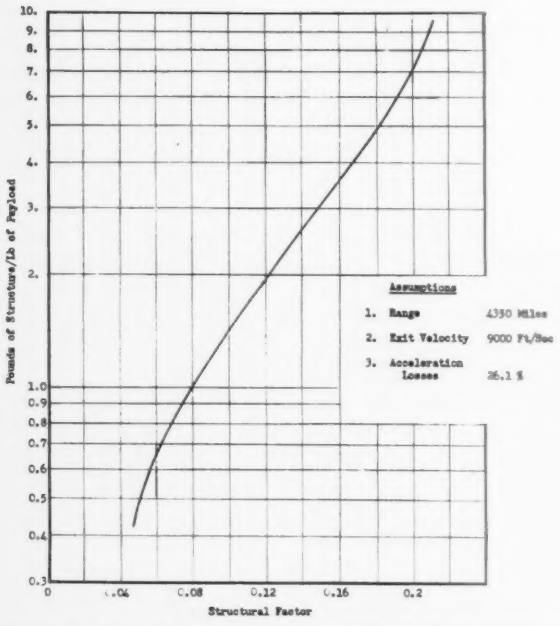

FIG. 4-5. Ratio of structural weight to pay load for a rocket airplane.

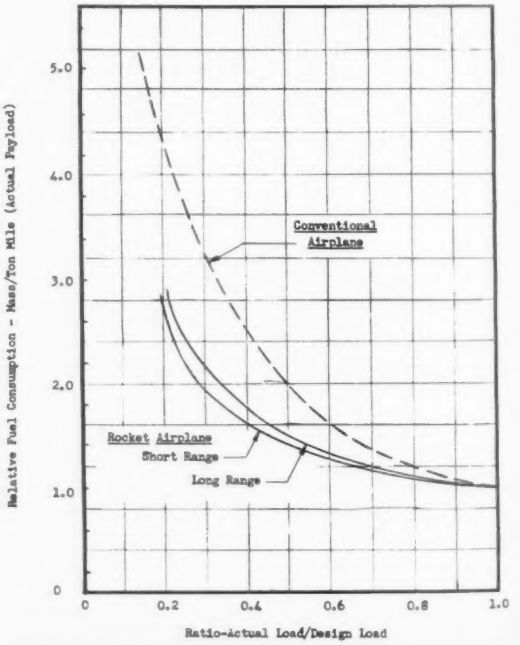

FIG. 4-6. Effect of load factor on propellant consumption.

TABLE 4-4
Structural Costs (See Text for Assumptions)

Structural Factor	A Weight Structure Weight Load	B Cost (cents/ton-mile)
0	0	0
0.05	0.48	0.41
0.10	1.40	1.20
0.15	3.3	2.83
0.20	7.0	6.0

(A) Air Freight

Slick Airways, Inc., will transport material between Los Angeles and New York at a cost of less than 12.1 cents/ton-mile. To qualify, a shipment must weigh over 10,000 lbs. and meet the requirements of *Commodity Rates No. 16*. American Airlines, Inc., will transport large shipments of personal effects at 12.3 cents/ton-mile.

The certificated air lines are able to carry substantial amounts of air cargo as supplements to scheduled passenger flights. Undoubtedly, Government subsidy helps reduce the cost of making such shipments.

In addition, there are many conveniently situated refueling stops between Los Angeles and New York. Consequently, the amount of the airplane's gross weight which must be devoted to fuel can be kept relatively small. The cost of long overwater shipments, where no convenient refueling points are available, is greater than quoted above.

Transocean Air Lines will quote rates varying between 40.2 and 41.6 cents/ton-mile for large shipments of household effects from Los Angeles to Honolulu, or Tokyo, or Sydney (Australia). Pan-American World Airways, Inc., quotes prices which are from 6 to 50 per cent greater for the same shipments.

(B) Railroad Freight

The Santa Fe railroad quotes a rate equivalent to 1.72 cents/ton-mile for shipping rolled steel sheets from Los Angeles to New York. This rate applies to a minimum carload of 40,000 lbs. The shipment must be in an open car not over $53^1/_2$ ft. long.

(C) Ocean Steamship

The American Transcontinental Freight Service will ship (via Panama Canal) rolled steel sheets from Los Angeles to New York at a base rate of 0.78 cent/ton-mile (based on the air-line distance).

(VI) PASSENGER FARES

The compilation of passenger fares given in Table 6-1 is representative of current travel fares. It is seen that travel by air or by steamship costs about 5 cents per passenger-mile, or more.

It has been air-line experience that the normal passenger, together with his baggage, averages about 200 lbs., or one tenth of a ton. Therefore, 10 passenger-miles equal 1 ton-mile. As shown in other portions of this study, there are good reasons for believing that the rocket-powered airplane can be operated at costs of much less than 50 cents/ton-mile—i.e., less than 5 cents/passenger-mile. It is therefore concluded that the rocket-powered airplane will be economically competitive with existing forms of passenger transportation.

(VII) PROJECTED COSTS OF AIR TRANSPORTATION

Any attempt to justify the rocket airplane on an economic basis should, in order to be prudent, be made in comparison with the cheapest competing form of air transportation. Accordingly, it is not enough to show that a rocket-propelled airplane can carry cargo more cheaply than existing aircraft. It must also be shown that the rocket airplane is competitive with the improved, but "conventional," types of airplane which will undoubtedly have evolved by the time rocket airplanes have been developed into a practical reality. Accordingly, in this section, a projection will be made of the possible direct operating costs of "air-breathing" airplanes.

It is not easy to predict the future cost of air travel. Instead, an attempt has been made to set lower bounds on the direct flying cost which may be achieved with several types of transport aircraft.

It seems appropriate to examine current costs of air transportation. These costs are used as a basis for projecting future costs. Based on the actual load carried, the average direct operating expenses of all domestic trunk lines in the United States in 1953 was 25 cents/ton-mile.[9] However, for the 12-month period ending June, 1953, The Flying Tiger Line, Inc., was able to attain a *total* operating expense of 13.09 cents/ton-mile on all-cargo aircraft (C-46's).[10]

A possible direct operating cost as low as 7 cents/ton-mile (100 per cent load factor) has been shown for the Lockheed 1049H airplane.[11] This figure will be used as a reference for projecting possible future cost reductions.*

The manner in which future direct flying costs were obtained is shown in Table 7-1. The Lockheed 1049H airplane, airplane A, was used as a reference standard. Column A lists a breakdown of the factors contributing to the total direct flying of this airplane. In columns B, C, and D, these factors are systematically altered. The objective in all three cases was to obtain the lowest possible direct flying costs. A load factor of 100 per cent was assumed in all cases.

* Another projection appeared on page 14 of the April, 1955, issue of *Aviation Age*.

"Lower turbojet operating costs were forecast by Sir Arnold Hall, Director of Britain's Royal Establishment. He stated that high subsonic turbojet transports will have direct operating costs of 21 cents per long ton-nautical mile (16.2 cents/ton-mile), as against 41 cents (34.4 cents/ton-mile) at present. Assuming present operating costs, total costs will be $44^1/_2$ cents (34.4 cents/ton-mile) as compared to $66^1/_2$ cents (51.5 cents/ton-mile).

"Sir Arnold favors use of *Mach 2 air liner for the London-New York route*. Plane would cruise at 45,000 to 55,000 ft. In the immediate future, he expects to see the straight-wing 500-m.p.h. turboprop, the 40-deg. swept 600 m.p.h. turbojet, or the 45–50-deg. swept delta transport in regular operation."

TABLE 4-5
Total Direct Flying Costs of a Rocket-Propelled Airplane (cents/ton-mile)

Assumptions		
Range	4,250 miles	
Load factor	0.80	
Acceleration allowance	26.1 per cent	
Propellants	liquid oxygen and oil	
Structural factor	0.10	0.20
Resultant direct flying costs		
Propellants	5.3	12.6
Flight crew	0.3	0.3
Everything else	1.5	7.5
Total	7.1	20.4

It should be emphasized that airplane A is an existing airplane. Its performance characteristics are guaranteed by the manufacturer. Airplanes B, C, and D are "paper" airplanes whose characteristics have been freely assigned so as to reduce direct flying costs. In all three cases, major technical advances must be made before these airplanes can be converted into practical realities. The magnitude of these difficulties should not be underestimated. They may equal or exceed the difficulties of developing a practical rocket-propelled airplane.

The alterations used to establish the characteristics of airplanes B, C, and D are as follows:

Airplane B

The effect of a 50 per cent reduction in the structural weight—i.e., empty weight—of the reference airplane is shown in column B. It is assumed that the maintenance, depreciation, and interest costs are directly proportional to the weight of the airplane.

Even if it were assumed that the total or gross of maintenance, depreciation, and interests are unaffected, the pay load of the plane would, in principle, be more than doubled by the changed structural allowance. Consequently, the direct flying costs in cents per ton-mile still would be cut in half.

Airplane C

Column C shows the cumulative effects of the following changes from the reference airplane (airplane A):

(1) A $33\frac{1}{3}$ per cent improvement in the lift/drag ratio attained during flight.

(2) A 50 per cent improvement in the thermal efficiency of the propulsion system.

(3) A reduction in the empty weight of the airplane from 73,000 to 51,500 lbs.

(4) A 50 per cent increase in the block-to-block flight speed.

As before, it is assumed that maintenance, depreciation, and interest costs are directly proportional to the weight of the airplane.

It is believed that, taken individually, the foregoing improvements are not extreme. The lift/drag ratio may be improved by flying at higher altitude and improved aerodynamic boundary-layer control. The required improvements in the thermal efficiency of the propulsion system could be attained by using stoichiometric mixture ratios in a simple turboprop engine cycle. Much of the required weight reduction could be obtained in the propulsion system. Finally, aerodynamic compressibility effects should not be severe at a flight speed only slightly in excess of 400 m.p.h.

Accordingly, the writer is willing to concede that direct flying costs may be as low as 2 cents/ton-mile for future subsonic cargo aircraft when operated at 100 per cent load factor.

Unless rather drastic changes are made in the assumed component costs, such as reducing the unit cost of air-frame fabrication to a small fraction of its present value, it is difficult to obtain projected costs which are appreciably less than 2 cents/ton-mile.

Airplane D

Flight at supersonic speed entails a penalty in lift/drag ratio, and hence in the size and weight of the power plant and in fuel consumption. A somewhat optimistic set of figures for supersonic airplanes is given in column D, Table 7-1. The assumptions made for airplane D are:

(1) The lift/drag ratio is half that of airplane A.[14]

(2) The power-plant efficiency is 50 per cent better than obtained in airplane A. The resultant range is therefore $0.5 \times 1.5 = 0.75$ that of the reference airplane.

(3) The block-to-block flight speed (1,120 m.p.h.) is four times that of the reference airplane—i.e., about Mach 2.

It is seen that, even with the above assumptions, the subsonic plane of column C is cheaper to operate than airplane D.*

Nuclear-Powered Aircraft

Some important conclusions concerning the economical characteristics of nuclear-powered airplanes can be obtained from Table 7-1.

Assume for the moment that the fuel cost of a nuclear-powered aircraft is zero. The remaining factors contributing to the direct flying costs are the salaries of the flight personnel and the maintenance, depreciation, and interest costs.

For brevity, the sum of the maintenance, depreciation, and interest costs will be called *structural costs*. Aside from the fuel costs, the most important difference between the nuclear-powered airplane and the chemically powered airplane would probably be the difference in the structural costs.

Initially, there will be added expenses in operating a nuclear-powered aircraft. The added complexities, the radiation hazards, and the inevitable "debugging" period—which always accompanies a radically new development—will add to the operating costs.

Assume that all these obstacles have been overcome and that the structural costs per unit weight for the nuclear propulsion system are identical to those of the rest of the airplanes. The fact remains that the weight

* See also "Profit," Section VII (C), p. 55.

breakdown of the nuclear-powered airplane will be less favorable than that of a chemically fueled airplane. As a result, the structural costs per ton-mile of the nuclear-powered airplane will be appreciably greater than those of its chemically fueled counterpart. One may therefore expect the nuclear-powered airplane to be most competitive in applications and embodiments that have a high ratio of fuel costs to structural costs. Airplanes B and D, especially D, are illustrative embodiments.

Applications in which the airplane has a high use factor, such as military patrol service or television broadcasting,* are examples of applications in which nuclear-powered airplanes have their best promise.

* Air-borne transmitters, flying at altitude, have been proposed as a method of increasing the receiver coverage of television broadcast stations.

TABLE 6-1
Passenger Fares—1955 (Exclusive of Taxes)

Destination	Name of Company	Distance from L.A. (miles)	Scheduled Time (hours)	Average Speed (m.p.h.)	Fare (dollars)	Rate (cents/passenger-mile)
Air						
Tokyo		5,520				
1st class	Pan American		29	190	650.00	11.8
Coach					488.00	8.8
Bombay		8,620				
1st class	Pan American		71.7	120	1,033.50	12.0
Coach					739.00	8.6
Sydney		7,480				
1st class	Pan American		36	208	675.00	9.0
Coach					540.00	7.2
Honolulu		2,530				
1st class	Pan American		10	253	168.00	6.6
Coach					125.00	4.9
New York		2,470				
1st class	TWA		7.8	316	158.85	6.4
Coach			9.8	252	99.00	4.0
San Francisco		340				
1st class	Western		1.7	204	22.05	6.5
Coach			1.8	186	13.05	4.0
Railroad						
New York		2,470				
1st class (roomette on Super Chief)	Santa Fe		58.5	42.2	161.32	6.5
2nd class (lower berth)			70.2	35.2	142.22	5.8
Coach			63.8	38.7	81.51	3.3
San Francisco		340				
Coach	Santa Fe		10	34	6.50	1.9
Steamship (passenger)						
Tokyo		5,520				
1st class	American President		336	16.4		
Most expensive					1,495.00	27.1
Cheapest					510.00	9.2
Sydney		7,560 (from Vancouver, B.C.)				
1st class	Orient Lines		504	15		
Most expensive					714.00	9.4
Cheapest					560.00	7.4
2nd class (intermediate or cabin)						
Most expensive					518.00	6.8
Cheapest					406.00	5.4
3rd class (tourist)						
Most expensive					364.00	4.8
Cheapest					272.00	3.6
Hawaiian Islands		2,530				
1st class	Matson (Lurline)		120	21		
Most expensive					1,250.00	49.3
Cheapest					145.00	5.7
Steamship (freighter)						
Honolulu (6 days weekly)	Matson	2,530	144	17.5	200.00	7.9
Sydney	Matson	7,480	504	14.8	449.00	6.0
Bus						
New York	Greyhound	2,470	80.2	30.8	56.70	2.3
Street car	L.A. Transit Line (No. 5 car)	19.5	1.5–1.6	12.5	0.47	2.4

Baggage Allowances

Air:	Domestic baggage allowance is 40 lbs./passenger for both coach and first class. Tokyo, Sydney, and Bombay—66 lbs. for first class and 44 lbs. for tourist.
Railroad:	Baggage limit is 150 lbs. for all classes.
Steamship:	Baggage allowance is 350 lbs. on most lines, 25 cu.ft. on some.
Bus:	Weight limit on baggage is 150 lbs.
Street car:	Unspecified; depends on strength of passenger.

TABLE 7-1
Projected Direct Flying Costs of Transport Airplanes

	Airplanes			
	A*	B	C	D
Basic assumptions†				
Relative lift/drag ratio	1.0	1.0	1.33	0.50
Relative engine efficiency	1.0	1.0	1.5	1.33
Flight speed, m.p.h.	280	280	420	1,120
Weights, kilopounds/airplane				
Structure	73	36.5	51.5	62
Fuel	30	30	15	30
Pay load	34	70.5	70.5	45
Total take-off weight	137	137	137	137
Derived quantities				
Range, miles	2,200	2,200	2,200	1,460
Output, kiloton m.p.h.	4.76	9.87	14.8	25.2
Direct flying costs, dollars/hour				
M, D, and I‡	197	98.5	139	167.5
Fuel**	113	113	85	601
Salaries	40	40	40	40
Total	350	251.5	264	809
Unit direct flying costs				
Unit cost, cents/ton-mile	7.34	2.55	1.78	3.21

* The characteristics of airplane A are based on information kindly supplied by Robert Reedy of Lockheed Aircraft Corporation. Airplane A is believed to be representative of contemporary transport airplanes.
† A 100 per cent load factor is assumed in all cases.
‡ Maintenace, depreciation, and interest charges.
** Fuel costs were assumed to be directly proportional to rate of consumption.

(VIII) CONCLUDING REMARKS

(*A*) *Necessary Assumptions*

The economic performance of a rocket-propelled airplane is largely determined by only three parameters: the lift/drag ratio, the structural factor, and the cost and performance of the rocket propellants. For most practical designs, the depreciation and maintenance costs of the airplane structure play a relatively minor role.

It cannot be emphasized too strongly that the technical possibilities of rocket-powered aircraft as discussed in this study are an extremely sensitive function of the performance parameters assumed. As seen in Fig. 8-1, the revenue-producing potential of the rocket-propelled airplane begins to be interesting only when δ is less than 0.20—i.e., only when the initial weight of each stage is more than five times its empty weight.

The obtainable aerodynamic lift/drag ratio is also a key parameter. As shown in Eq. (1), p. 34 of the September REVIEW, the range obtained by a given rocket-powered airplane during the momentum gliding portion of its flight is inversely proportional to the lift/drag ratio. Thus the propellant costs, which constitute the major portion of the total direct flying costs, will be doubled if the lift/drag ratio obtained is 3, rather than 6, as assumed throughout this study. It should also be noted that Eq. (1) has a singularity when $v_0^2 = Rg$. In other words, the importance of high lift/drag decreases as the initial speed of the airplane approaches the satellite speed.

(*B*) *Operational Problems*

Several possible operational problems have not been discussed. For example:

(1) *Aerodynamic Heating*—Phenomena associated with aerodynamic heating have been extensively discussed in the literature. The writer is convinced that, by careful design, the external surfaces of the rocket airplane can be made to radiate heat off into space at a rate equal to the influx caused by aerodynamic heating.

(2) *Weightlessness*—A second possible operational problem is the exposure to abnormal acceleration fields to which the passengers and cargo of a rocket airplane are subjected. The physiological and psychological effects of strong, supranormal acceleration fields on human beings have been studied extensively and are well known. The acceleration portions of the flight of the rocket airplane can be programmed in a manner which will not unduly tax human passengers. However, during the gliding portion of the flight, the rocket airplane and its occupants will be exposed to a gravitational field of less than 1*g*. The possible effects on human beings of prolonged exposure to an acceleration-free environment—i.e., weightlessness—are not known. However, even at ranges of 6,000 miles, the net acceleration on the passengers during gliding flight is always well over 0.5*g*. It is believed that most of the psychological and physiological problems of weightlessness would be unimportant under these conditions.

(3) *Guidance*—The piloting and navigation requirements of a long-range rocket airplane are very different from those of current transports. The magnitude of the initial accelerations must be accurately monitored. Mid-flight fixes must be made at high speed. It is almost certain that high-speed electronic computers will be used and that guidance will be largely automatic.

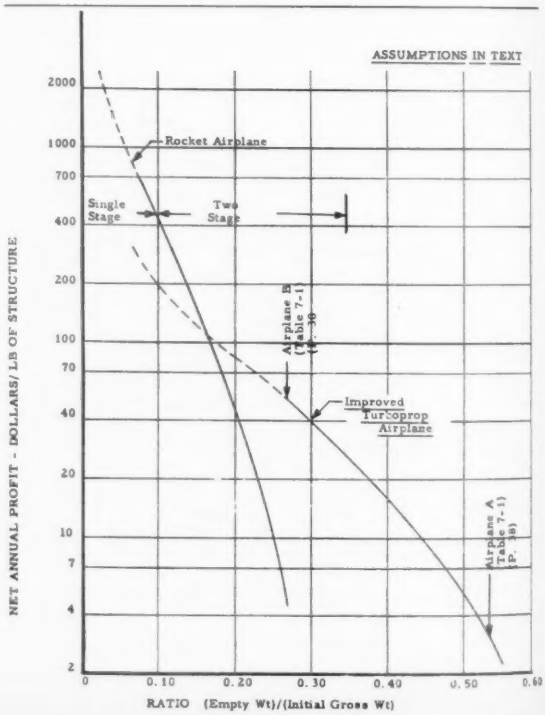

FIG. 8-1. Annual profit on airplane structure.

(C) *Profit*

(1) *Benefits of High Flight Speed*—The operator of an airplane would presumably like to maximize the return on his invested capital. In this study, attention has been focused on estimated direct flying cost.

The flight speed is also important. The total annual revenue produced from the operation of a given airplane is directly proportional to the ton-miles moved and hence is directly proportional to the flight speed. Since a rocket airplane may be expected to fly from two to ten times as fast as any air-breathing competitor, it should be expected that the annual profit per dollar invested in an airplane will, in many cases, be greater for a rocket-powered airplane than for an air-breathing airplane, even though the profit per ton-mile is less.* These facts are illustrated in Table 8-1.

(2) *Profit Comparison*—The increased rate of profit which ensues from increased flight speed is shown also by Fig. 8-1. The assumptions used in computing Fig. 8-1 are as follows:

(a) *For both airplanes:* For both the rocket and the conventional air-breathing airplane, it is assumed that revenue is received at the rate of 20 cents/ton-mile and that the indirect flying costs are 5 cents/ton-mile; that the load factor is 0.60; and that the structural costs—i.e., maintenance, depreciation, and interest costs—are directly proportional to the weight of the structure. The rocket airplane was assumed to cost \$60/lb. of empty weight, and the air-breathing airplane was assumed to cost \$25/lb. of empty weight.

(b) *For rocket airplanes:*

Range	3,000 miles
Average exhaust velocity	10,000 ft./sec.
Cost of propellant mixture	0.877 cent/lb.
Acceleration allowance	26.1 per cent
Lift/drag ratio	6.0
Structural and other costs	Computed as in Section IV

(c) *For air-breathing airplanes:* The properties of the air-breathing airplane ("Improved Turboprop Airplane" of Fig. 8-1) are identical to those of airplane A, Table 7-1, except that the weight of the structural parts is reduced and the operating costs have been adjusted to a load factor of 0.60.

(D) *Comments*

In the opinion of the writer, it is much easier to obtain a structural factor of 0.20 in a rocket airplane than in an air-breathing airplane. The prospects of attaining a practical, conventional airplane whose ratio of empty weight to initial gross weight (ordinates of the graph, Fig. 8-1) is appreciably less than 0.30 are believed to be minuscule. It was for this reason that the "Improved Turboprop Airplane" curve in Fig. 8-1 was dotted at the left-hand end.

The situation is very different in the case of a rocket airplane. The weight of the propulsion engines is almost trivial. Heavy wings are not required to obtain adequate aerodynamic properties. There is every reason to believe that the structural factors of less than 0.20 can be obtained.

It is concluded that, under the iterated conditions, the rocket-propelled airplane can be made to yield profit at a rate which is substantially greater than that obtainable with any competing subsonic airplane.

Computations may be performed, using other initial assumptions. The assumed revenue rate can be reduced. Comparisons can be made between the rocket airplane and airplane D (or airplane C) instead of with

* Optimizing flight speed: It will be found that the profit rate obtained with rocket airplanes can be increased if spoilers are used to decelerate the airplane during the terminal time-consuming portions of the gliding flight. In this way, the average flight speed of the rocket airplane can be substantially increased, at the expense of a slightly increased propellant consumption. This feature is exactly analogous to that obtained in the operation of subsonic transport airplanes. Maximum profit is obtained by operation at a flight speed substantially in excess of that at which maximum range (or minimum fuel consumption) is obtained. The increased rate at which revenue is produced (more ton-miles per hour) more than compensates for the added cost incurred by the increased fuel consumption.

TABLE 8-1
Net Profit Rates

Assumptions
Revenue is produced at the rate of 10 cents/ton-mile and indirect flying costs are 3 cents/ton-mile.
Direct flying costs of air-breathing airplanes are given in Table 7-1.
Rocket airplane has a design range of 3,000 miles and is identical with Case A of Table 4-3 except that an average effective exhaust velocity of 10,000 ft./sec. was assumed.

Results

Properties	Airplane A	B	C	D	Rocket
Load factor	1.0	1.0	1.0	1.0	0.6
Flight speed, miles/hour	280	280	420	1,120	5,000
Total direct flying cost, cents/ton-mile	7.34	2.55	1.78	3.21	5.37
Burden, cents/ton-mile	3.0	3.0	3.0	3.0	3.0
Total operating costs, cents/ton-mile	10.34	5.55	4.78	6.21	8.37
Net profit, cents/ton-mile	(0.34) (loss)	4.45	5.22	3.79	1.63
Net hourly output, ton-miles/kip of airplane structure*	65	270	287	406	1,485
Net hourly profit, dollars/hour of operation/kip of airplane structure	(2.21) (loss)	12.01	15.00	15.40	24.20

* One kip = 1,000 lbs.

airplane B. In almost every case, it will be found that the results of such computations do not change the major conclusion reached in this study—namely, that the rocket-propelled airplane can be an economical form of long-range, terrestrial transportation.

APPENDIX 1

Fuel Costs

The information which follows has been added to help substantiate the fuel costs assumed in the study.

Oil

Crude oil brings about $2.00 per barrel in the United States. A barrel contains 42 gal.* The density of oil ranges from 0.7 to 1.0g/cm.^{3}. Cost of the crude oil is, accordingly, 0.6 to 0.8 cent/lb.

Richfield and Shell will deliver diesel fuel at 12 cents/gal. if purchased in tank car lots. Standard of California charges 13 cents/gal., f.o.b., El Segundo, Calif. Specific gravity is above 0.86. Cost per pound is, therefore, 1.68 cents.

Diesel fuel is a higher quality fuel than needed for rocket applications. For example, Standard supplies a distillate fuel oil at 4.76 cents/gal. (about 0.7 cent/lb.), f.o.b., El Segundo. This price is as cheap as the crude oil from which it is obtained.

The oil price assumed in this study, 2 cents/lb., may seem unduly conservative. However, the price of oil has been advancing steadily for the past two decades. There is every reason to believe that it will continue so in the future.

Hydrogen

Methane (CH_4) contains 25 per cent hydrogen by weight. Natural gas, as sold for heating and illuminating purposes, contains more than 90 per cent methane. The wholesale price of methane in California currently runs about 18 cents per 1,000/ft.^{3}. Since 1,000 cu.ft. of natural gas contains 10 lbs. of hydrogen, the cost of the contained hydrogen is 2 cents/lb. To this cost must be added the cost of chemically separating the hydrogen from the native methane and, for use in rockets, the cost of liquefying the gas. As shown in reference 5, the cost of liquefying hydrogen is at least 1 cent/lb. In addition, the cost of natural gas has been steadily increasing. In view of these facts, the assumed 8 cents/lb. does not appear to be unduly conservative.

APPENDIX 2

Cost of Placing Material in a Satellite Orbit

The methods described in this study may be used to compute the cost of placing material in a satellite orbit about the earth. Two numerical examples follow:

Assumptions

	Case A	Case B
Structural factor	0.10	0.10
Effective exhaust velocity, ft./sec.	11,000	10,000
Required acceleration (total), ft./sec.	27,000	27,000
Acceleration allowance, ft./sec.	3,000	3,000
Cost of propellant mixture, cents/lb	0.8	0.8
Cost of structural parts, dollars/lb.	60	60
Service life of vehicle, hours	10,000	10,000
Time required for each trip, hours	4	4
Ratio (cost of repairs and maintenance)/(depreciation cost)	0.71	0.71
Number of stages	2	2

Results

Ratio of take-off weight to pay load	41.1	66
Ratio of total propellant weight to pay load	35.4	57.6
Cost of propellants/lb. pay load, cents/lb.	28.4	47.0
Weight of structure/weight pay load	4.7	7.4
Maintenance, interest, depreciation, and repairs of structure, cents/lb. pay load	19.7	31.0
Total cost of placing 1 lb. in satellite orbit, cents	48.1	78.0

APPENDIX 3

Properties of Nuclear-Powered Rocket Airplanes

Introduction

The properties and cost of nuclear propulsion are discussed in this appendix. It has been assumed that all problems associated with nuclear shielding, heat transfer, and chemical reactions at elevated temperatures have been solved.

The most simple type of rocket-utilizing nuclear energy is one in which a working fluid is pumped through a heat exchanger and into an expanding nozzle. A nuclear reactor (or pile) serves as the source of heat for the heat exchanger. After being heated, the working fluid expands in the nozzle and is ejected at high velocity.

Selection of Working Fluids

Clearly, many desirable properties may be listed for the propellant used for the working fluid. The physical, chemical, and nuclear characteristics of the working fluid are important. For the purposes of this study, however, it can be shown by simple arguments that the most important single characteristic of a working fluid to be used in a commercial nuclear-powered rocket airplane is its cost. Thus, since the oil-oxygen chemical propellant mixture costs less than 1 cent/lb., the cost of the working fluid used in the nuclear-powered aircraft should not exceed this figure. In making this assertion, it is tacitly assumed that the exit velocity of the gas in both the chemical and the nuclear cases is comparable. As will be shown later, this is indeed the case.

Water

Consider water as a working fluid. In order to have an exit velocity of 9,000 ft./sec., as was assumed for the

* 1 gal. = 231 in.^{3}.

TABLE A

Assumptions
Effective exit velocity = 18,000 ft./sec.
(Empty weight)/(Full weight) stage 1 = 0.15
Acceleration allowance = 26.1 per cent

Initial Velocity (kilo. ft./sec.)	Range (miles)	Propellant Consumption (lbs./ton-mile)	No. of Stages
7	825	2.06	1
12	2,880	1.33	1
16	5,740	1.25	1
20	10,820	1.06	2

oil-liquid oxygen rocket drive, the water must be heated to a temperature in excess of 3,000°F. before expansion in the nozzle.

It is true that the necessary heat content, 1,600 B.t.u./lb., can be obtained at temperatures less than 1,600°F. However, any attempt to obtain a complete conversion of this thermal energy to kinetic energy by means of expansion in the nozzle, will not succeed. The latent heat of vaporization of water is about 1,000 B.t.u./lb. This energy can be realized only by condensing the gaseous water into a liquid. There is a large body of experimental evidence which shows that this conversion cannot be obtained effectively in a nozzle. A similar type of two-phase flow, using solid aluminum oxide, or magnesium oxide, mixed with gaseous hydrocarbons, has been suggested by Sänger.[4]

Some experiments with saturated steam might be worth while. The design and development of a light weight heat exchanger which will heat steam to more than 3,000°F. is, in the writer's opinion, not a simple task. At this temperature, steam will react chemically with most refractory materials. It is concluded, therefore, that it will probably be technically difficult to develop an exit velocity of 9,000 ft./sec. using steam heated by a nuclear reactor.

An alternative approach might be the development of a catalyst which will accelerate the dissociation of superheated steam into its component elements, thereby decreasing the net molecular weight and increasing the resultant exit velocity, with the pressure ratio across the nozzle remaining constant. The writer has not qualified himself to comment on the feasibility of such a proposal.

Effect of Decreased Exit Velocity

To avoid the development difficulties associated with high-temperature heat exchangers, it may be appropriate to consider the following gambit By expanding steam isentropically from 4,000 psia and 1,600°F. to a pressure of 0.2 psia, an exit velocity of 6,900 ft./sec. could be obtained.

Under most conditions, the gross weight of a rocket airplane would be increased by a factor between two and three if the exit velocity were decreased 9,000 ft./sec. to 6,900 ft./sec. If it is assumed that the cost of the water is trivial, the direct flying cost of the larger airplane will consist of only the nonpropellant components of the total direct flying cost. If these nonpropellant costs are evaluated for the nuclear-powered rocket airplane in the same way as in the chemical-powered rocket airplane, it will be found that the direct flying cost is still on the order of 4 cents/ton-mile. A structural factor of 0.12 was assumed.

A direct flying cost of 4 cents/ton-mile is enticingly small However, the problems and weight penalties of the required nuclear shielding must be solved in detail before a fair comparison can be made.

Combined Nuclear and Chemical Propulsion

A possible method of combining chemical and nuclear propulsion is to use the nuclear rocket for the booster stage and use the chemical rocket for the cargo-carrying stage. In these circumstances, it will sometimes be found that the total direct flying cost is less than in either a pure nuclear- or a pure chemical-propelled rocket.

By using a towline, an unmanned, powered, booster stage, operated by remote control, may be easily separated by a safe distance from the chemically propelled pay-load stage. The shielding necessary to provide protection (to the pay load) from nuclear radiation will be thereby reduced.

Other Working Fluids—Hydrogen

Water is comparatively cheap, and hence it is an attractive working fluid. However, by using a material having lower molecular weight, such as hydrogen, a greater exit velocity may be obtained, pre-expansion temperature remaining fixed. For example, it seems quite possible to obtain exit velocities as high as 18,000 ft./sec. by expanding high-pressure hydrogen from about 2,000°F. into a vacuum. Under these conditions, the propellant consumption is given in Table A.

By comparison with Fig. 3, it can be seen that the propellant consumption has been reduced to a quantity which is in no case less than one third that used by a chemical-powered plane burning hydrogen and oxygen. The cost of the pure hydrogen used in the nuclear case is more than three times the cost of the hydrogen-oxygen mixture burned in the chemical case. Consequently, it is manifest that the cost of propellant has not been reduced by changing to a nuclear source of heat.

It may be concluded from the preceding discussion that the economic appeal of "conventional" nuclear rockets is sharply limited by the extremely modest performance improvements which can thereby be obtained. Using the best possible material—hydrogen—an exit velocity only twice that of chemical propellants was obtained.

Supervelocities

Several methods have been proposed to use the energy of nuclear fission to obtain dramatic increases in the effective exit velocity of rockets. Included are:

(1) Nonthermal acceleration of mass: electric acceleration of ions, use of proton or neutron beams, and directional polarization of the fission fragments.

(2) Use of stellar temperatures in the working fluid.

Both these techniques have been repeatedly described in the literature during the past decade. It is the writer's conviction that neither technique can be perfected enough to be practicable as a source of propulsion of terrestrial, manned, or rocket-propelled aircraft within the present century.

Epilogue

It has been presumed throughout this entire study that the designer of rocket-propelled airplanes has effected the most economical compromise between the various parameters which enter into the design of the airplane. These key parameters are:

(1) The cost of the propellant mixture used as rocket fuel.

(2) The performance (specific impulse) attained from the propellants selected.

(3) The lift/drag ratio obtainable in the airplane at hypersonic flight speeds.

(4) The portion of the gross weight of the airplane which must be allocated to structure and dead weight.

To obtain flight performances approaching those given for rocket-propelled airplanes in this report is a difficult and challenging job. It is only by pushing every factor to the limit that successful designs can be achieved. Accordingly, it has been assumed throughout this study that the airplane designer is both courageous and competent.

It is freely admitted that there are probably many errors in this study. These errors may be in concept, in assumptions made, in the numerical calculations, or in the details of the conclusions drawn. It is the writer's conviction, however, that these manifold transgressions do not invalidate the main conclusion—namely, that the rocket-propelled airplane can be an economical form of terrestrial transportation. He will be more than pleased if the reader is brought to share, even in small part, this conviction.

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An appeal is made for recognition of national defense as one of the basic industries of the United States. The author warns that speed in the air alone does not determine superiority and advocates a search for more innovations and newer concepts—"hard work on the right problems."

Aims of the Air Force Development Program in Aeronautics and Propulsion

Brig. Gen. Marvin C. Demler*
Air Research & Development Command, USAF

Introduction

In the past half century, man's mobility, or the rate at which he can get about, has increased twentyfold —from the maximum railroad speed of about 100 m.p.h. at the beginning of the century to speeds approaching 2,000 m.p.h. In all the previous history of man's existence, there had been only a twentyfold increase in man's speed from the time he first learned to get about upright on two legs—and most of that increase had been made possible in the last 100 years since the invention of the steam engine.

Who among us, reflecting on these facts, has not wondered where we are going, what the next 25 years will bring? Particularly in these days of cold war and technological competition, the question of where we are going, or where we *can* go with the application of sufficient effort on the right problems, is extremely critical.

As a nation, we have tremendous resources, but they are not unlimited, and we must exert our best efforts to ensure that they are applied where usefulness and possibility of success are optimized.

The purpose of this paper is to describe our planning process in technological development in aeronautics and propulsion and to outline some of our general aims.

Plotting Past Aircraft Performance

From the beginning of powered flight, increases in speed and altitude have been dependent on power-plant development and on advancements in aerodynamics and structures.

Each major gain in speed was associated with one or more major design improvements. These advances, if depicted in graph form, would show curves of noticeable perturbation—the result of the acceptance and concentrated development of the gas-turbine and rocket engines. Research aircraft performance consistently surpasses the performance of operational aircraft; however, the difference between two speeds at any time appears to be about constant. Such a curve, if projected into the future, might prove useful as a guide to where we might be able to go.

An easy way to do this is to replot this curve on semilog coordinates. By so doing, we find that the curve has the characteristics of an exponential or compound interest function and comes out as a straight line.

The immediate reaction of some would be that this is some sort of legerdemain, that there is a limit to how far this may be projected. Taken far enough, we would find that before long we would be traveling faster than the speed of light! Certainly there are limitations as to how far into the future one may extrapolate a curve of past aircraft performance; we must first evaluate and thoroughly understand these limitations before our plot can become a useful forecasting tool.

Significance in Repetition

Let us examine for a moment the validity of the curves just considered. The exponential shape is repeated time and time again when one studies curves depicting general growth in this country since 1900. Consistent repetition should not be casually brushed off as a mere coincidence. Repetition of this kind has meaning, and one should take a second look at things to attempt to discover exactly why such similarity occurs.

For a moment, let us study a plot of the Gross National Product and National Wealth versus time since 1900. Gross National Product, an economic yardstick representing goods and services available to the United States on a yearly basis, shows a definite upward trend. The increase of GNP (based on the 1929 dollar) is almost exponential, the only interruptions to this trend being brought about by wars and the depression.

Presented before the IAS Indianapolis Section, April 16, 1956.
* Deputy Commander for Research & Development.

Power Use Indicates Growth

A hint to United States industrial growth can be found when one surveys the increased industrial consumption of electrical power since 1900. Increased power consumption implies greater industrial production. This fact can be seen when one considers the total yearly value of manufacturing since 1900. The monetary value of industry has many other parameters mixed in with it, but it is indicative of general "dollars-and-cents worth" of industry. In spite of the slope fluctuations induced by major economic changes, the various parameters discussed all vary in nearly an exponential manner with time.

It is interesting, if not unique, that the maximum attainable aircraft speeds should be related to time in a manner similar to the variation that various economic and social parameters have with time. The similarity in growth occurs so frequently and with such consistency that one can safely employ these curves as guideposts to future programs. Returning for a moment to our consideration of maximum aircraft speeds vs. time, we can draw the following conclusions:

(a) Our curve would represent the maximum attainable aircraft speeds regardless of the type of engine or plane. If we call such achievements "aeronautical progress," we find, for a moment, that aeronautical progress is dependent on time in the same manner as the economic and social growth of our country.

(b) With minor deviations, we would find that the plot follows a characteristic exponential slope. We must realize that this is only from 1900 to the present time. It would be extremely hazardous, and possibly erroneous, to assume blithely that this mathematical relationship can continue on into the far distant future. We have more than doubled attainable aircraft speeds in the last 10 years, and our plot should predict to a fair degree attainable aircraft speeds in the next 10 to 20 years. One should exercise some degree of reservation in extrapolating our curve well beyond 20 years.

Superiority Is Not Determined by Speed Alone

The curve we place significant importance on was only for maximum attainable speed vs. time. Speed itself is not the only parameter which evaluates aeronautical superiority, and we must strive to improve other aircraft characteristics in order to maintain overall air superiority. In general, our objective may be defined as the ability to fly higher, farther, faster, to arrive at the point of decision with superior fire power, and to be able to do this any place in the world, any time.

One realizes that this mission cannot be achieved with any one type of vehicle but rather by the use of a variety of vehicles each with its own specialty. The combination of vehicles acting as a team possesses superiority far greater than any single component of the team.

Having gone through the exercise of extrapolation and projection of trends, we note some postulated aircraft requirements which we would like to achieve. Normally, however, we do not formally state a requirement for specific performance until there is reason to believe that the goal can be achieved. We must therefore identify those factors which contribute to higher, farther, and faster performance and see what can be done about improving them. Progress along the exponential growth curves is not automatic but the result of much hard work on the right problems.

Let us examine a few well-known indexes of merit for jet engines, for example, to see what might be expected in the way of future trends for performance gains from that source.

Jet-engine specific fuel consumption, a ratio of fuel consumption to thrust, decreased rapidly during the initial development stages of the gas turbine. Effort expended to this end provided a worth-while saving to aircraft; however, in the last few years further reduction of this factor has been diminishing. Therefore, dramatic gains in aircraft performance in the future based on improved engine s.f.c. are not to be expected from a normal projection of this curve.

The previous discussion applies equally well to the variation of jet-engine specific weight with time. In the early stages of development, remarkable strides in the reduction of specific weight were achieved; significant and gratifying progress is still being made in reduction of engine weight. However, beyond some point, this curve must also level out.

Technical Break-Throughs

While contributing substantially to improved aircraft performance and essential to the superiority of particular types of aircraft, progress of the kind represented by these two illustrations will not let us advance indefinitely along the exponential growth curves. On the one hand, the rate of change of "progress" is decreasing, but, to stay on the desired growth pattern, the rate of change of "progress" must continually increase. We must therefore seek what we are in the habit of calling "technical break-throughs"—those innovations and new concepts which can radically alter direction of normal progress. Technical breakthroughs might be thought of as the revolutionary rather than the evolutionary advancements.

A few technical break-throughs which have yielded significant returns are the jet engine, sweptback wing, rocket engines, and the more recent area progression rule.

Although the theoretical use of jet propulsion as an aircraft propulsive system has never been disputed, the ability to engineer high-efficiency blade cascades and to develop high-temperature metals essential for jet-engine performance was doubted. The rewards of being able to fly at extreme altitudes and at high speeds were not fully grasped by industry and Government

when the jet engine was conceived, and its development was subsequently deferred.

The simplicity of design and the high thrust to weight and thrust to frontal area ratios, compared to piston engines, make the gas turbine extremely attractive as a propulsive engine. Today's high speeds and altitudes would not have been possible without the acceptance and perfection of the jet engine.

With the acceptance of the jet engine and the advent of today's high speeds, it became evident that conventional aircraft wing designs of the time were no longer adequate. Compressibility effects of the air passing over the wing had a detrimental effect on aircraft performance at high speeds. The swept wing, with its relatively low velocity component perpendicular to the wing, enabled aircraft to achieve the theoretical speeds capable with the jet engine and with little to no reduction in overall performance.

The visualization of a rocket propulsion engine for aircraft has been with man ever since the realization that flight was possible. The stumbling block to the use of this form of propulsion has been known equally as long—that of making the rocket engine versatile and controllable with a maximum degree of safety.

The War and Postwar Periods

World War II and the postwar period opened the eyes of the United States to the definite possibility of speeds many times faster than those capable with piston and gas-turbine engines. The speeds desired could be achieved only with rocket engines; it was with this incentive that a concentrated effort was made to solve the long-standing rocket development problems. The returns from this project have certainly warranted the effort put forth, and, in many cases, the returns have far exceeded their planners' expectations.

Supersonic aircraft are subjected to numerous shock waves of varying strength in normal flight. Prediction of the location and strength of all shock waves under various flight conditions is a difficult task. A more difficult task, prior to development of the area progression rule, was to optimize aircraft design so that shock-wave effects produced in flight could be minimized. NACA undertook such a study, and the now famous area progression rule was the eventual outcome. The use of this rule has enabled air-frame designers to make relatively small changes in experimental and prototype aircraft and obtain marked performance improvements. Efficient operational limits have been improved, and many of the major obstacles threatening the performance of prototype aircraft have been notably reduced, if not removed. The development of the area progression rule has been a most timely break-through, and it will remain a major aircraft achievement for many years to come.

The search for possible technical break-throughs and smaller, but nonetheless important, improvements, and their recognition and exploitation are major aims of our technical development program. Some items, which at this time appear to offer substantial gains, are airfoil boundary-layer control, jet thrust reversal, and vertical take-off aircraft.

With the high-speed, swept-wing aircraft of today, small increases in lift represent significant increases in overall performance. Lift, to a large extent, can be increased by proper control of the boundary layer around the airfoil.

Establishment of the ARDC

The desire to control airfoil boundary layers has long been with us, and workable devices have been developed to enhance circulation and, consequently, lift. The magnitude of the problem was relatively small prior to the jet age, and it is only now with our present and proposed supersonic speeds that we must take a second look and advance our thinking about boundary-layer control. Items such as vortex generators and jet flaps, to mention just a few, promise rewarding returns to the Air Force and warrant future development.

The use of jet-engine thrust for purposes other than solely forward motion offers promising returns. Complete or even partial jet reversal can amount to an appreciable saving in length of runway needed for aircraft landings. When one looks ahead to the proposed sizes of future aircraft, one must also consider the required size of the runway for such planes. Increased length of runway and facilities amounts to a sizable investment, and any reduction in required landing length promises major reductions in supporting facilities.

The development of a vertical take-off operational aircraft affords the Air Force very promising returns. Not only can air base facilities be reduced but the overall versatility of the aircraft can be greatly increased.

It was to make sure that research and development received the attention it must have, if we are to progress along the growth curve, that the Air Force established the separate Air Research and Development Command. In the ARDC we have an organization that, while providing general engineering service for the entire Air Force, is sufficiently removed from the routine of everyday production and maintenance problems to permit concentration on the problem of providing superior weapons for tomorrow.

I think the need for almost exclusive concentration on research and development is especially important in the function of long-range planning. The planning process in military research and development involves a continuing amalgamation of information on science and strategy—testing what is possible in view of the state of science and invention against what is useful in the attainment of military objectives. It is important that this analysis be made in the context of the future and not necessarily conditioned by how it fits in with the existing scheme of things. Too many of the great military developments in the past grew out of ideas which had long been known but had not been recognized simply because the application was thought of

(*Continued on page 70*)

General formulas are presented for computing the thermal stresses and curvature in a long beam when the rise in temperature at any location in the beam cross section is given and when the coefficient of expansion and Young's modulus are known functions of temperature.

Thermal Stresses and Deformations in Beams*

Samuel Levy†
General Electric Company

(1) Introduction

Because of significant aerodynamic heating of the airplane in high-speed flight, it becomes necessary to predict the structural stresses and deformations which may result from this heat. The heat is primarily the result of the adiabatic temperature rise corresponding to the stagnation temperature which is approximately proportional to the square of the speed. The aerodynamic behavior of the air in the vicinity of the surface is such that the temperature of the surface, after equilibrium is reached, is usually somewhat less than the stagnation temperature. The ratio of the equilibrium temperature rise to the stagnation temperature rise is the recovery factor and must be known in any particular thermal stress analysis.

During the time the surface is heating to its equilibrium value, the rate at which heat flows to the surface depends on the properties of the boundary layer in laminar flow and on the scale of turbulence in turbulent flow. In a sense, the surface air acts as an insulating blanket. The quantity of heat transferred can be considered as the product of the temperature difference times a heat-transfer coefficient. The heat-transfer coefficient can be expected to vary widely since the flow of air over the airplane surfaces changes both with position on the airplane and with speed. It can be expected to increase when the air density increases or when the boundary layer becomes thinner.

The loss of heat from a surface by radiation may become appreciable at high temperatures since the radiation of heat varies as the fourth power of the absolute temperature. Heat can also flow to a surface by radiation—solar radiation being the chief source of such heat flow. The radiation equilibrium temperature at high altitude of an insulated surface normal to the sun's rays can vary from about −40°F. for a white painted surface to about 830°F. for a bright metal surface. The same surfaces normal to the moon's rays are at about −436°F. and −387°F., respectively. With only starlight, the temperature is about −454°F.

The complexity of heat transfer to an airplane surface[1–3] makes it desirable for the structural designer to examine the extent to which the stresses and deformations of his structures are dependent on a precise description of the temperature conditions. The first portion of this report will examine this question for beams heated from one side and show that the stresses and deformations corresponding to a given maximum temperature are relatively insensitive to temperature distribution. The second portion of this report will consider simple approximate formulas for estimating temperature distributions. Heating from one side only is considered. In the case where the heat conditions differ on the two sides, combining the solutions for each side separately can give the desired result.

(2) Structural Effects of Temperature

(2.1) *General Equations*

Let the temperature rise at any location on a beam cross section be given by T and consider the variation of T with position along the beam length to be negligible. Choose x and y axes (Fig. 1) in any convenient location for computation. Denote the coefficient of thermal expansion of the beam material by α and Young's modulus by E. Assuming plane sections remain plane, the elastic stress in the beam is given by

$$\sigma = E(-\alpha T + \delta + \gamma x + \beta y) \qquad (1)$$

where

δ = extension of beam per unit length at origin of coordinates

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γ = curvature of beam about y axis
β = curvature of beam about x axis

Eq. (1) applies to beams for which the thermal effects do not induce chordwise stresses. Box beams having relatively few chordwise ribs and beams having a short chord length fall into this category. In solid beams having a chord length greater than several times the thickness, however, the chordwise stresses require that E in Eq. (1) be replaced by an effective modulus $E/(1 - \mu)$, where μ is Poisson's ratio. Near the wing root where chordwise bending is restrained, the effective modulus is $E/(1 - \mu)^2$ rather than E. In the subsequent development, E will be used to signify the effective value of Young's modulus.

When the thermal stresses alone are to be found, the external loads carried by the beam are zero, and the stresses are only the internal stresses resulting from the temperature distribution. We have then,

$$\iint \sigma dA = \iint \sigma x dA = \iint \sigma y dA = 0 \qquad (2)$$

where the integrals are taken over the cross section and dA is an element of cross-sectional area. Substituting Eq. (1) in Eq. (2) gives

$$\left.\begin{aligned} \delta \iint E dx dy + \gamma \iint x E dx dy + \\ \beta \iint y E dx dy = \iint \alpha T E dx dy \\ \delta \iint E x dx dy + \gamma \iint x^2 E dx dy + \\ \beta \iint xy E dx dy = \iint \alpha x T E dx dy \\ \delta \iint E y dx dy + \gamma \iint xy E dx dy + \\ \beta \iint y^2 E dx dy = \iint \alpha y T E dx dy \end{aligned}\right\} \qquad (3)$$

Knowing T as a function of x and y and knowing α and E as functions of T, it is possible to evaluate the integrals in Eq. (3) and to solve for δ, γ, and β. Substituting them in Eq. (1) gives σ.

(2.2) *Rectangular Solid Beam, E and α Constant*

We will first consider the effect of the temperature distribution on the stress distribution and deformation of the simplest beam, a solid rectangular one, with constant E and α, having the simplest temperature distribution—that is, varying only from top to bottom.

The heated part of the cross section will be taken to extend a distance d into the beam (Fig. 2) and to have a constant excess temperature T_M. The resulting stress distributions and curvatures for various values of the dimensionless penetration distance d/b are shown in Fig. 3. We note that, as the heat penetrates, the maximum tensile and compressive stresses are always located at the bound between the hot and the cold parts of the beam and that their absolute magnitude is about 0.5 $E\alpha T_M$ for $0.2 < d/b < 0.8$. The stress approaches a maximum magnitude of $E\alpha T_M$ as the heat boundary approaches a surface. The curvature β has a maximum absolute value of 1.5 $\alpha T_M/b$ when $d/b = 0.5$ and exceeds 0.96 $\alpha T_M/b$ in absolute value in the range $0.2 < d/b < 0.8$. It is of interest to observe that the curvature varies inversely as the beam

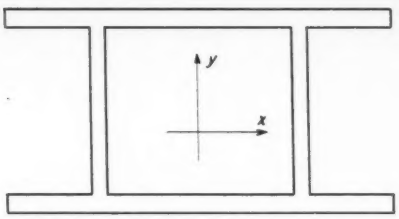

FIG. 1. Typical beam cross section. Axes may be placed at a location in the beam cross section which is most convenient for computation.

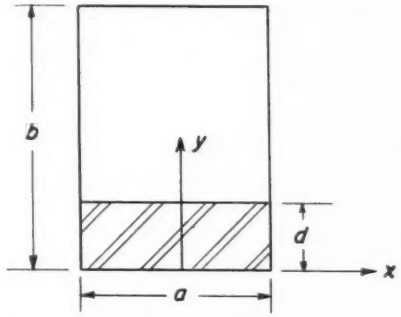

FIG. 2. Cross section of heated rectangular beam; crosshatched part at a constant excess temperature T_M.

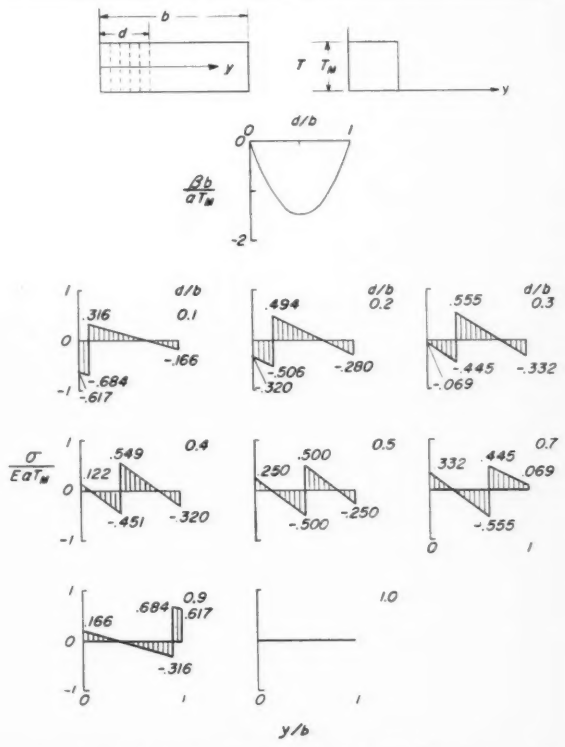

FIG. 3. Variation of curvature and stress distribution with depth of penetration of a "step" temperature distribution in a solid rectangular beam.

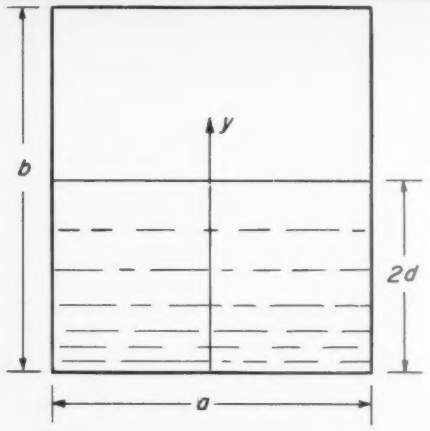

FIG. 4. Cross section of heated rectangular beam; cross-hatched part at excess temperature which varies from T_M at surface to 0 at a penetration of $2d$.

depth b and directly as the product αT_M, and that, for $d/b < 0.1$, the stresses in the cool portion of the beam and the curvature increase in proportion with the depth d of heat penetration.

Taking the temperature of the heated part of the cross section to vary from an excess temperature T_M at the surface to 0 at a depth of $2d$ (Fig. 4) gives the stress distributions and curvature shown in Fig. 5. We note that in this case the maximum compressive stresses occur at either the hot or cold surface while the maximum tensile stress occurs at the bound between hot and cold. The maximum compressive stress

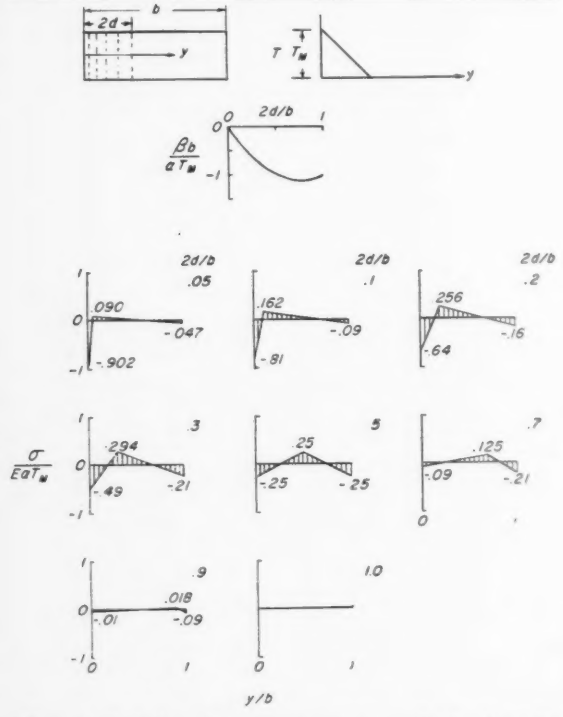

FIG. 5. Variation of curvature and stress distribution with depth of penetration of a "ramp" temperature distribution in a solid rectangular beam.

is $E\alpha T_M$ for small penetration. For a penetration distance $2d$ greater than half the depth b, the compressive stress never exceeds $0.25\ E\alpha T_M$. The tensile stress never exceeds $0.296\ E\alpha T_M$ and has this maximum value when the penetration $2d$ is one third of the depth b. The curvature β has a maximum absolute value of $1.125\ \alpha T_M/b$ when the depth of penetration $2d$ is 0.75 of the beam depth b. For $(2d/b) > 0.5$, the curvature β always exceeds $\alpha T_M/b$. For $2d < 0.1$, the effect on the stresses in the cool portion of the beam and on curvature of doubling $2d$ is equivalent to doubling T_M.

It seems possible that during the initial stages of heating, the stresses may depend primarily on the total heat stored. To provide such a comparison, Fig. 6 has been prepared. It is evident that, for equivalent values of d, the heat stored will be the same for both "ramp" and "step" temperature distributions. Comparison of the curves corresponding to equivalent heat content shows that, for values of d/b up to about 0.05, the maximum stress and curvature agree within about 1 per cent. For $d/b = 0.1$, the corresponding surface stresses and stresses in the cool portions of the beams agree within about 2 per cent of the maximum stress.

(2.3) *Rectangular Box Beam, E and α Constant*

We will next consider the effect of temperature distribution on the behavior of a box beam having the cross section shown in Fig. 7. The wall thicknesses of this beam are taken as one one-hundredth of the corresponding wall widths. The response of such a box beam to temperature will more nearly approximate the response of an airplane wing than will the response of the solid beam treated in section (2.2). The beam is again considered to have E and α constant.

The stress distributions and curvatures for a "step" temperature distribution are shown in Fig. 8. We note that the maximum absolute value of curvature β is $1.135\ \alpha T_M/b$ when the heat has penetrated to half the beam depth and that, for $0.2 < d/b < 0.8$, β exceeds $\alpha T_M/b$. The maximum compressive and tensile stresses occur at the bound between hot and cold parts of the beam and are about $0.6\ E\alpha T_M$ for $0.2 < d/b < 0.8$. For moderate values of d/b, we find that, as long as the heat stored is constant [$T_M(49 + 100d/b)$ constant for $0.01 < d/b < 0.99$], the stress in the cold portion of the beam and the curvature are relatively unaffected. Comparison of Figs. 3 and 8 shows the effect of cross-sectional shape on stress and curvature for this temperature distribution. The differences in the two figures are less than about 50 per cent when $0.2 < d/b < 0.8$.

The stress distributions and curvatures for a "ramp" temperature distribution are shown in Fig. 9. The maximum curvature β in this case is $1.035\ \alpha T_M/b$ and occurs when the heat has penetrated a distance e of about three fourths of the beam depth b. When e/b exceeds 0.5, the curvature β always exceeds $\alpha T_M/b$. Fig. 9 shows that the maximum tensile stress which

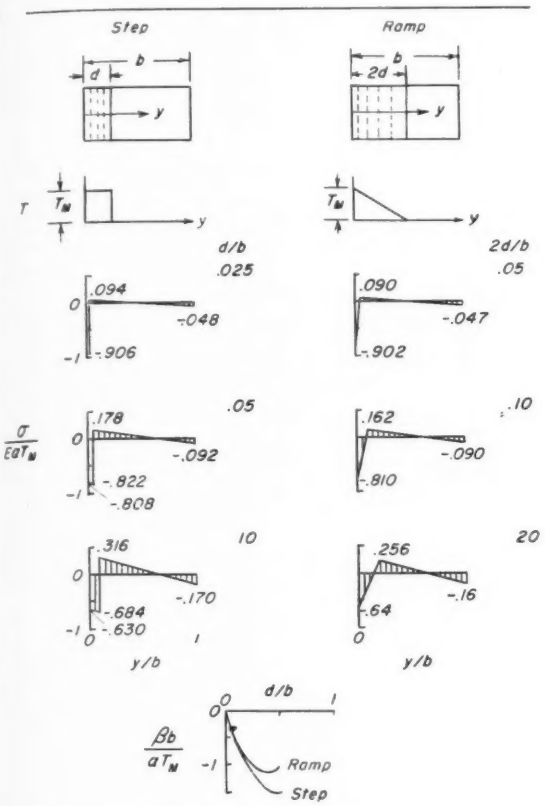

FIG. 6. Comparison of stress distributions and curvatures in a solid rectangular beam for "step" and "ramp" temperature distributions having the same total heat content.

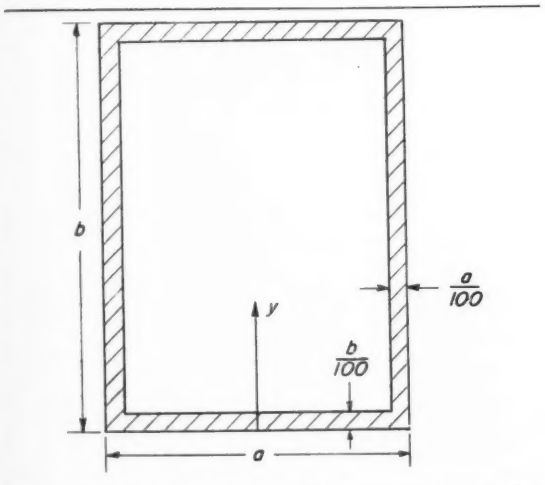

FIG. 7. Cross section of rectangular box beam considered in Figs. 8, 9, and 10.

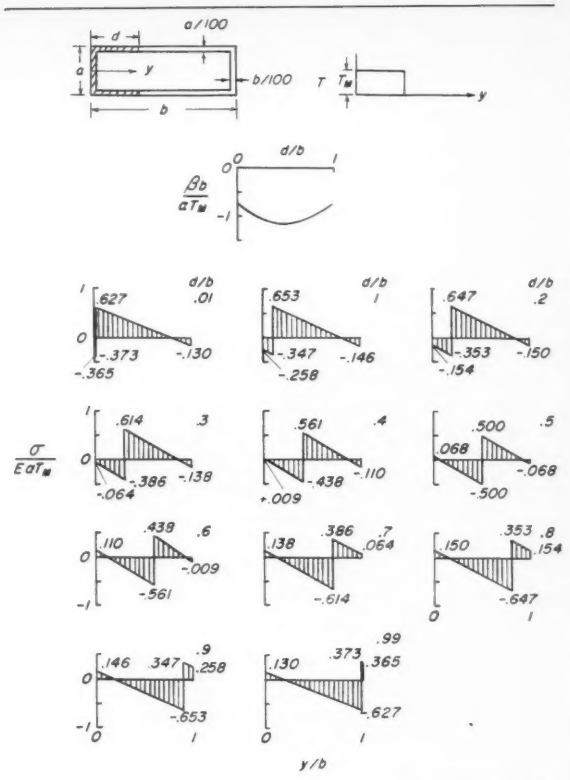

FIG. 8. Variation of curvature and stress distribution with depth of penetration of a "step" temperature distribution in a rectangular box beam.

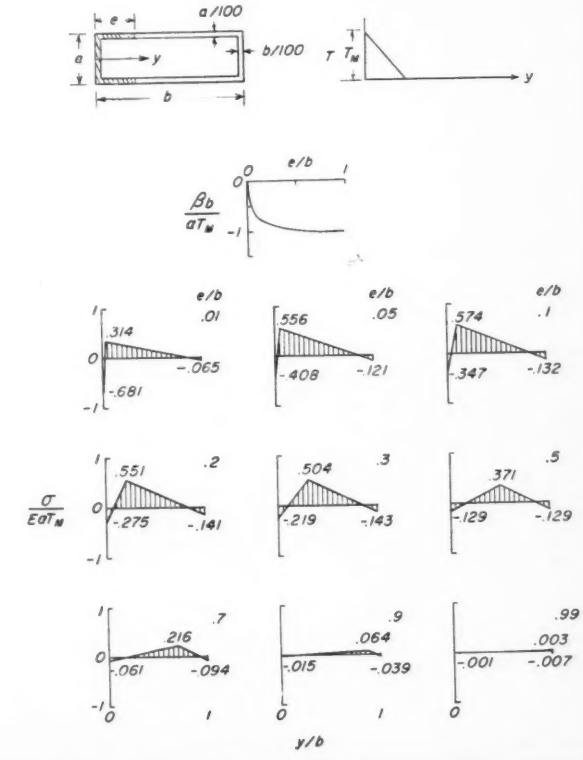

FIG. 9. Variation of curvature and stress distribution with depth of penetration of a "ramp" temperature distribution in a rectangular box beam.

occurs at the boundary between the hot and cold parts of the beam is about 0.57 $E\alpha T_M$ when the depth of penetration e of heat is about one tenth of the beam depth b. For $0.01 < e/b < 0.6$, the maximum tensile stress lies between 0.29 $E\alpha T_M$ and about 0.57 $E\alpha T_M$. The maximum compressive stress on the heated side of the box drops in absolute value from $E\alpha T_M$ to 0.681 $E\alpha T_M$ when the heat penetrates through the thickness of the heated wall. For a penetration distance e greater than about one fourth of the beam depth b, the compressive stress never exceeds 0.25 $E\alpha T_M$ in absolute value. Again we find that, for $e/b < 0.1$, the stress in the cold portion of the beam and the curvature are relatively unaffected as long as the total heat stored is constant, $T_M(98 + 100e/b - 0.49b/e)$ constant for $0.01 < e/b$. Comparison of Figs. 5 and 9 shows that the effect of cross-sectional shape on curvature for a "ramp" temperature distribution is less than about 10 per cent when $e/b > 0.4$, while its effect on stress is more significant, the box beam having roughly twice the maximum tensile stresses and half the maximum compressive stresses of the solid beam.

Fig. 10 shows a comparison of "ramp" and "step" temperature distributions in a box beam for the same maximum temperature T_M and for the same total heat absorbed. It is evident that, except in the immediate vicinity of the heat boundary, the stress distributions are nearly identical for moderate values of heat penetration. For $e/b < 0.3$, the surface stresses and stresses in the cool portion of the beam agree within 7 per cent, and the peak stresses at the heat boundary, which occur at different values of y/b in the two cases, agree within 30 per cent. The curvatures agree within 1 per cent up to $e/b = 0.4$ and differ by less than 14 per cent at $e/b = 1.0$.

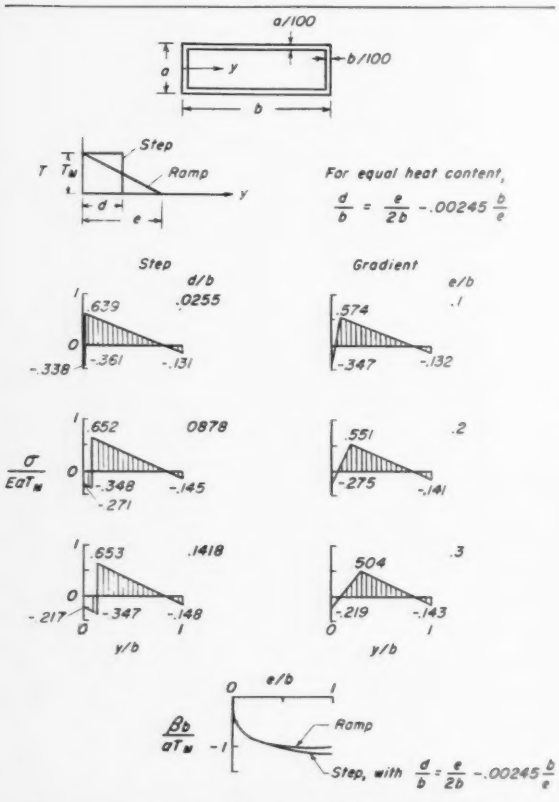

FIG. 10. Comparison of stress distributions and curvatures in a rectangular box beam for "step" and "ramp" temperature distributions having the same total heat content.

(3) Effect of Rate of Heating on Stress

In the previous discussion we have considered the stresses in beams resulting from various temperature distributions. We have found that, for moderate depths of heat penetration in a given cross section, the stress in the cold portion and the curvature depend primarily on the total heat content; in the heated portion of the cross section the stress depends, in addition, on the maximum temperature T_M.

There are strong indications that ordinarily a maximum stress of the order of $E\alpha T_M$ will be present only during the initial stages of heating when the depth of penetration is low. For the most likely "ramp" temperature distributions (Figs. 5 and 9), the stress is less than $1/2\ E\alpha T_M$ for penetrations of temperature greater than about one third the beam depth. In those cases where a time delay, due to thermal resistance in the surface air or to the time required to accelerate to high speed, allows the heat to penetrate to more than about one third the beam depth before the maximum surface temperature is reached, it is reasonable to expect an alleviation in stress of about one half.

(3.1) *Approximate Formula for Temperature*

To estimate temperature, we will make several simplifying assumptions:

(1) The distribution of temperature is always of the "ramp" type—that is, the temperature decreases linearly with distance from the surface. This seems warranted by the results presented in earlier portions of this report which show that the stresses and curvatures are primarily dependent on the total heat content and surface temperature and are only secondarily affected by the temperature distribution.

(2) The heating effect of the air can be described by specifying a rise in air temperature T_A and a heat-transfer coefficient c, describing the blanketing effect of the surface air. In the case of accelerated flight,[1] T_A and c would more likely be time dependent, and the following theory would require corresponding revision. Assumption (2) is suitable, however, for demonstrating how to use assumption (1) in developing a theory and is a reasonable representation of the meager data available.

(3) Radiation is neglected. This assumption limits the theory to temperatures below about 500°F. It could be replaced by a more realistic assumption when a theory for higher temperatures is required.

(3.1.1) Solid Beam Temperature

Consider the case of heating of a solid beam (Fig. 11). The temperature rise is taken as dropping from T_M at the surface to 0 at a distance d from the surface. The rate of heat flow q_1 (B.t.u./sec.) to the beam surface is

$$q_1 = Ac(T_A - T_M) \tag{4}$$

where

A = surface area (ft.²)
$(T_A - T_M)$ = temperature drop through surface air (°F.)
c = heat-transfer coefficient (B.t.u./sec. ft.² °F.)

The rate of heat flow q_2 away from the surface is

$$q_2 = kA(T_M/d) \tag{5}$$

where

T_M/d = temperature gradient in beam material (°F./in.)
k = conductivity of beam material (B.t.u. in./sec. ft.² °F.) assumed constant at the average value for the temperature range

Equating q_1 [Eq. (4)] and q_2 [Eq. (5)],

$$d = (k/c)\ [T_M/(T_A - T_M)] \tag{6}$$

The quantity of heat Q (B.t.u.) stored in the beam, as long as the heat has not reached the far side of the beam, is

$$Q = u.1dT_M/2 \tag{7}$$

where u = heat capacity of material (B.t.u./ft.² in. °F.) assumed constant at average value for temperature range.

The quantity of heat which reaches the beam in a time t (sec.) is approximately

$$Q = Act[T_A - (2/3)T_M] \tag{8}$$

where $[T_A - (2/3)T_M]$ = approximation to average temperature difference through surface air (°F.). [Factor 2/3 is based on a variation of T_M as square root of t. The adequacy of this approximation is considered in section (4.3).]

Equating the values of Q in Eqs. (7) and (8) gives, after eliminating d with Eq. (6),

$$t = (3uk/2c^2)\ [T_M^2/(T_A - T_M)\ (3T_A - 2T_M)] \tag{9}$$

Since the stresses are unlikely to exceed $1/2\ E\alpha T_A$ if the penetration d exceeds one third the beam depth before $T_M = T_A$, it is interesting to note that the penetration d [Eq. (6)], when the surface temperature T_M reaches one half its limit value T_A, is

$$(d)_{T_M = 1/2\ T_A} = k/c \tag{10}$$

The corresponding time elapsed t [Eq. (9)] is

$$(t)_{T_M = 1/2\ T_A} = 3uk/8c^2 \tag{11}$$

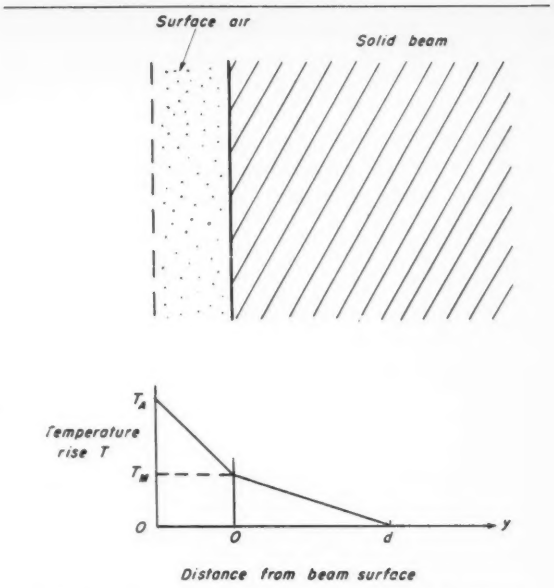

FIG. 11. Estimation of temperature and rate of heating.

(3.1.2) Box Beam Temperature

The surface of a box beam subjected to uniform external heat conditions would be expected to be cooler at the points of web attachment than it is at points midway between webs. An accurate assessment of this effect does not appear warranted, however, because of both the insensitivity of stress and curvature to temperature distribution and the presence of other unresolved uncertainties, such as the conductivity of joints.

The method we will use for estimating box beam temperatures will be approximately as accurate for T_M as a function of time as the method for solid beams [section (4.1.1)]. The estimation of penetration depth will, however, be only about half as good. In view of the insensitivity of the maximum tensile stress to penetration depth in the important range of depths from one twentieth to one third of the beam depth (Fig. 9), it is believed that this will not be a source of large errors.

To determine the effective depth of penetration of heat, we will modify Eq. (4) for a solid beam to take account of the fact that some of the heat flowing down the web comes from the surface sheet.

The heat flowing into the web from the surface directly in front of it is

$$ch_2l(T_A - T_M)$$

where

h_2 = web thickness (in.)
l = spanwise length of heated portion (in.)

During the initial stages of heating, before the depth of penetration d equals the surface wall thickness h_1, this is all the heat flowing to the web. When d is substantially greater than h_1, it can readily be shown

that there is a lateral heat flow in the heated wall, toward the juncture with the web, of magnitude

$$\sqrt{ckh_1}(T_A - T_M)$$

Combining these two terms with an empirical factor $d^4/(d^4 + 10h_1^4)$ to take account of the transition range where d is nearly equal to h_1 gives

$$q_1 = ch_2l\left\{1 + [d^4/(d^4 + 10h_1^4)]\sqrt{kh_1/ch_2^2}\right\} \times (T_A - T_M) \quad (12)$$

for the rate of heat flow into the web.

For the rate of heat flow down the web we again use Eq. (5) with A replaced by h_2l in this case.

$$q_2 = kh_2l(T_M/d) \quad (13)$$

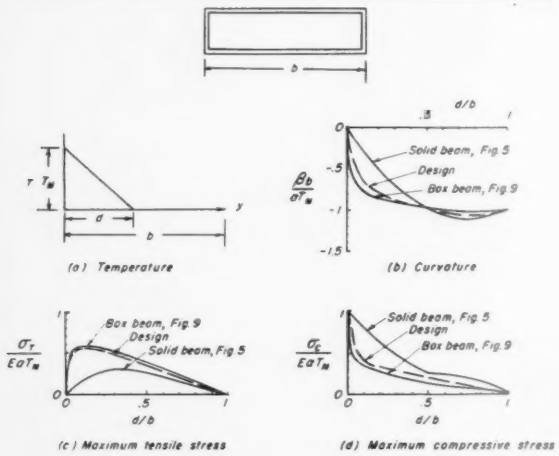

FIG. 12. Effect of depth d of heat penetration on curvature β, maximum tensile stress σ_T, and maximum compressive stress σ_C, for "ramp" temperature distribution.

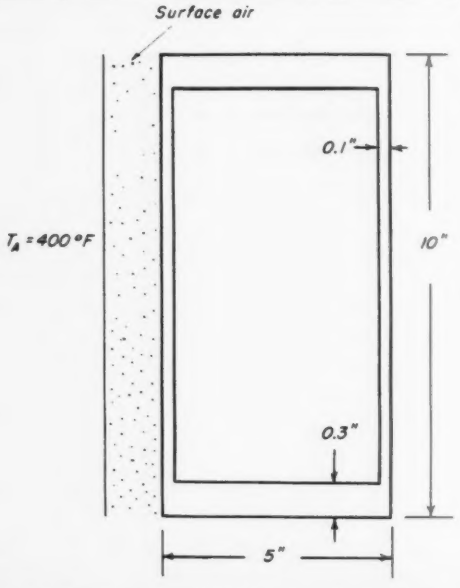

FIG. 13. Box beam considered in time history example; rise T_A in environment temperature over initial beam temperature is 400°F.

Equating q_1 and q_2 gives

$$d = \frac{k}{c}\frac{T_M}{T_A - T_M}\frac{1}{1 + \left(\frac{d^4}{d^4 + 10h_1^4}\sqrt{\frac{kh_1}{ch_2^2}}\right)} \quad (14)$$

Eq. (14) is readily solved for d by trial and error since the factor $d^4/(d^4 + 10h_1^4)$ is less than 0.1 for $d < h_1$ and between 0.9 and 1 for $d > 3.1h_1$.

The quantity of heat Q (B.t.u.) stored in the beam for $h_1 < d < (b - h_1)$ and an assumed "ramp" temperature distribution is given by

$$Q = ul\left\{wh_1[1 - (h_1/2d)]\,T_M + 2h_2d(T_M/2)\right\} \quad (15)$$

where w = width between webs (in.). In Eq. (15) the drop in heated wall temperature near the web is neglected. For the quantity of heat which reaches the beam in a time t (sec.), we again use Eq. (8) with A replaced by $l(w + 2h_2)$,

$$Q = l(w + 2h_2)ct[T_A - (2/3)T_M] \quad (16)$$

Equating the values of Q in Eqs. (15) and (16),

$$t = \frac{u\left\{wh_1[1 - (h_1/2d)]T_M + h_2dT_M\right\}}{c(w + 2h_2)\,[T_A - (2/3)T_M]} \quad (17)$$

(4) Time History of Stress, Temperature, and Curvature

In Fig. 12 are shown the variations of maximum tensile and compressive stresses and curvature with depth of heat penetration for the solid and box beams considered in sections (2.2) and (2.3) when subjected to a "ramp" temperature distribution. Included also in this figure is a design curve selected to fall between the computed curves for the box and solid beams and weighted to fall closer to the box beam results. It is suggested that this design curve be used for estimating stresses in the case of heating from one side only where other uncertainties, such as the heating conditions, make a more thorough analysis unnecessary. It should be noted that superposition, for heating from two sides, should not be used here since the location of maximum stress is likely to differ for the two types of heating.

For estimating maximum stresses and curvatures in a beam under steady heating conditions prior to penetration of heat throughout the beam, the following procedure is proposed:

(1) For a range of values of surface temperature T_M, given beam constants and given temperature environment, compute t and d from Eqs. (14) and (17) for box beams or from Eqs. (6) and (9) for solid beams.

(2) Using Fig. 12 and the value of d obtained in step (1) above, determine the curvature and stress ratios corresponding to the values of T_M selected. From these compute β, σ_T, and σ_C.

(3) Plot β, σ_T, and σ_C as a function of t.

(4.1) *Example of Time History Computation*

We will consider a box beam having the geometry shown in Fig. 13. We will select the following values

of the constants:

c = 0.03 B.t.u./sec. ft.^{2} °F.
k = 0.033 B.t.u. in./sec. ft.^{2} °F.; stainless steel, approx.
u = 5.2 B.t.u./ft.^{2} in. °F.; stainless steel, approx.
E = 26,000,000 lbs./in.^{2}; hot stainless steel, approx.
α = 9.4 × 10^{-6} in./in. °F.; hot stainless steel, approx.
T_A = 400°F.
b = 5 in.
h_1 = 0.1 in.
h_2 = 0.3 in.
w = 9.4 in.

The computations are carried out in Table 1 and are plotted as curves (a) in Fig. 14. It is seen that, in this case, the maximum stress is a tension of about 35,000 lbs./in.^{2}. The maximum compression is about 21,000 lbs./in.^{2}. Both of these stresses occur when the penetration is roughly one fourth of the depth. The maximum curvature is about -0.0007 in.$^{-1}$ and occurs when the heat is nearly through the beam.

(4.2) *Effect of Heat-Transfer Coefficient c*

For comparison, the above computation was repeated with c = 0.01 B.t.u./sec. ft.^{2} °F.—one third as much as for curves (a), Fig. 14—and with c = 0.09—three times as much as for curves (a), Fig. 14. The purpose of this computation was to evaluate the effect of substantial changes in the surface-air heat-transfer coefficient since this coefficient is both difficult to determine and likely to vary with time and position. The results are shown in Fig. 14 as curves (b), c = 0.01 B.t.u./sec. ft.^{2} °F., and as curves (c), c = 0.09 B.t.u./sec. ft.^{2} °F. It is seen that increasing the surface-air heat-transfer coefficient results in larger maximum stresses, curvature, and rate of heating. The maximum tensile stress is 21 per cent higher for curve (c) and 24 per cent lower for curve (b) than for curve (a).

(4.3) *Check on Simplifying Temperature Assumption*

In order to check the simplifying assumption in Eqs. (8) and (16)—namely, that the average surface temperature up to time t is 2/3 T_M where T_M is the surface temperature at time t—the average temperature up to time t was computed from the values given in Table 1 and is plotted as a function of time in Fig. 15 together with the value 2/3 T_M. The two curves differ by less

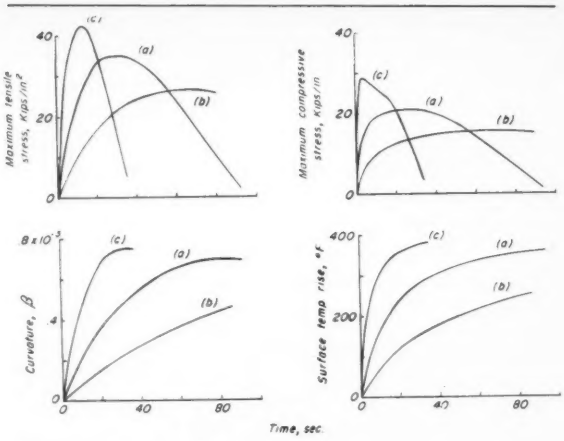

FIG. 14. Examples of maximum stress, curvature, and temperature time history in a box beam. Curves (a), c = 0.03 B.t.u./sec. ft.^{2} °F.; curves (b), c = 0.01 B.t.u./sec. ft.^{2} °F.; curves (c), c = 0.09 B.t.u./sec. ft.^{2} °F.

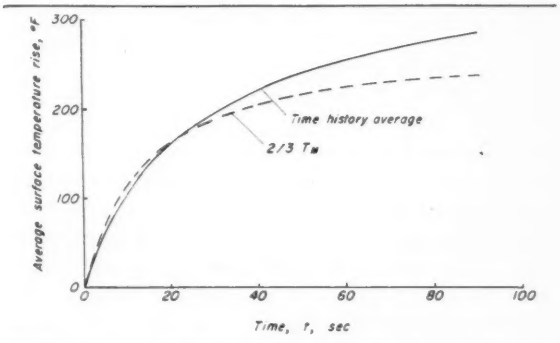

FIG. 15. Average surface temperature rise up to time t computed from time history of temperature rise in Table 1 and computed as 2/3 T_M where T_M is the surface temperature rise at time t.

than 12 per cent up to a time t = 60 sec. and agree exactly at t = 22 sec. Inspection of corresponding curves (a) in Fig. 14 indicates that the maximum stresses occur at about the time when agreement of the two curves in Fig. 15 is best and that the surface is at about 340°F.—or nearly fully heated—by the time t = 60 sec.

(5) Discussion and Conclusions

The results presented in this report are in agreement with the following generalizations for a beam heated from one side only:

TABLE 1
Example of Computation of Stresses and Curvature

T_M (°F.)	50	100	150	200	250	300	340	360
t (sec.)	1.44	4.06	7.74	13.11	21.12	35.9	61.6	91.2
d (in.)	0.1276	0.2113	0.327	0.526	0.871	1.568	2.96	4.70
d/b	0.0255	0.0423	0.0654	0.1052	0.1741	0.314	0.592	0.940
$\sigma_C/E\alpha T_M$	0.76	0.62	0.49	0.40	0.34	0.28	0.16	0.02
$\sigma_T/E\alpha T_M$	0.42	0.50	0.53	0.55	0.54	0.47	0.27	0.03
$\beta b/\alpha T_M$	−0.34	−0.46	−0.52	−0.66	−0.78	−0.91	−1.04	−1.02
σ_C (lbs./in.^{2})	9,300	15,100	17,900	19,500	20,800	20,500	13,300	1,800
σ_T (lbs./in.^{2})	5,100	12,200	19,400	26,900	33,000	34,400	22,400	2,600
$10^6\beta$ (in.$^{-1}$)	−32	−86	−147	−248	−367	−513	−665	−690

(a) Curvature varies inversely as the beam depth b and directly as the product of the coefficient of expansion and maximum temperature rise, αT_M. The curvature does not exceed 1.5 $\alpha T_M/b$ and, for a wide variety of conditions, it is about 1.0 $\alpha T_M/b$.

(b) For moderate values of heat penetration, the stress in the cool portion of a beam and the curvature depend primarily on the total heat stored. For depths of penetration below about one tenth the beam depth, differences are less than about 2 per cent.

(c) Cross-sectional shape has a significant effect on the stress for a given temperature distribution; the box beam considered in this report has about twice the tensile and half the compressive stresses of a solid beam for a "ramp" temperature distribution.

(d) If the temperature is approximately of the "ramp" type and if time delay, due to thermal resistance in the surface air or to the time required to accelerate to high speed, allows the heat to penetrate to more than about one third the beam depth before the maximum surface temperature T_M is reached, the stresses can be expected to be less than about 1/2 $E\alpha T_M$, and the curvature can be expected to be about $\alpha T_M/b$.

(e) The assumption that the temperature distribution is of the "ramp" type allows a marked simplification in temperature calculations and is justifiable for stress and curvature calculations as long as the total heat content can be determined with fair accuracy. Formulas based on this assumption are presented for a bea subjected to constant aerodynamic heating from on side.

(f) Changes in the surface-air heat-transfer coeffi cient have a marked effect on the rate of heating bu only a moderate effect on the maximum stresses an curvatures.

Major uncertainties in the determination of the de tailed temperature distribution in beams arise fro lack of knowledge regarding joint conductivity and th surface-air heat-transfer coefficient. Less serious un certainties result from difficulty in taking into accoun spanwise heat flow, convection, and radiation. Th results presented in this report indicate that, fo beams, these uncertainties may have a marked effec on temperature distribution and rate of heating whil having only a moderate effect on stress and curvature It is believed that this will also be true for other mor complicated structures, and it is suggested that ad vantage be taken of this favorable situation when ever stresses and deformations are of primary interest

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Aims of the Air Force Development Program . . .

(Continued from page 61)

in terms of the limitations of the contemporary scene. The ARDC is doing everything it can to disprove the old saw that the military are always developing weapons to fight the last war.

Suppose we do discover a "break-through"—some innovation which requires development or some basic scientific phenomenon which now can be applied to military use through improved technology—promising tremendous military advantage, possibly even changing the balance of power among nations? Here again we believe ARDC is designed and equipped to carry through on development. The success of the Manhattan District in developing the atom bomb in World War II has fostered a tendency to call for new Manhattan Districts whenever big new opportunities or problems are presented. What people really want is the assurance that all possible talent and effort are being concentrated on the important projects. In a sense, all ARDC might be thought of as a Manhattan District to do research and development for the Air Force. In this one Command are all the varied functions from basic research to flight test, the services, and the facilities necessary to the development of modern weapons, which can be directed to the problems of highest priority. Our thinking is to the future, and our reaction time is fast.

Conclusion

In this planning and development process, our plans in ARDC are but the road maps, and our operations are giving the green lights of priority and the distribution of the fuel. The real job—hauling the freight—is up to American science and industry. National defense should be recognized for what it has become—one of the basic industries, along with food, clothing, and shelter. The American system of enterprise and industry has shown clear superiority before the world in the provision of food, clothing, and shelter in abundant quantities. Let us not fall down in the field of national defense.

A. F. Bonnalie*
United Air Lines, Inc.

Safety and Economic Aspects of Flight Simulators

Flying is not learned any place but in the airplane. The dual control system of instruction originally used by the Wright brothers in 1908 is still the basis for flight instruction, but the flight simulator has its place in teaching those things that are not directly the skill of flight.

THE ADVENT OF the flight simulator wherein the prototype for a given airplane costs in the neighborhood of a million dollars has been a shock that has not, even as yet, fully been absorbed by those responsible for the training of air carrier flight personnel. The recommendation by the Doolittle Committee several years ago for more extensive use of such a device fell on barren ground with few exceptions—notably the military. Even prior to the report in question, the military, drawing upon their experience with many types of synthetic device during World War II, had wholeheartedly accepted the crew trainer, and the U.S. Air Force is by far the largest user of flight simulators.[1]

There are probably in the neighborhood of 200[1] such machines—both military and commercial—now in existence, of which United Air Lines, Inc., presently has four. When it is appreciated that the first electronic simulator was put into service by Pan American World Airways, Inc., only 7 years ago (early in 1949), the tremendous advances that have been made become apparent.[3, 4]

Obvious questions arise as to the completeness of simulation needed for the devices to be satisfactory instructional equipment. Sometimes the terms used are "whole-task" or "part-task" simulation.[1, 5, 6, 7] In the studies that preceded the purchase of the first group of simulators, United Air Lines adopted the whole-task principle with a few minor exceptions.

The instructional procedures used have something to do with the extent of the simulation required. The mission method generally used by the Air Force requires full simulation of fuel consumption, weather problems, rough air, and even lightning.[2, 5, 8] The procedures adopted by United Air Lines do not, in general, parallel actual flight. Rather the field to be covered is broken down into lessons of 2 hours' duration which cover material that is self related. In fact, one of the great advantages of the simulator in instruction is that it does not have to fly around to get into position or to change altitude. Accordingly, a great deal of time economy is possible when repeated instruction on a phase of flight is given. In this manner, it is felt that the capabilities of the simulator as an instructional tool are utilized to the utmost.

On the other hand, the thinking relative to the use of the coming DC-8 simulator is in the direction of the mission method for at least a part of the instruction. This airplane will be such a radical change in weight, speed, power, and environment of flight that much more of a conditioning problem will be involved. Also, new areas of simulation, including visual landing, are being studied.

Consideration has also been given to the part-task simulator or even to a generalized type. Some feel that a great deal can be done with such a machine at a considerable reduction in cost because of either simpler simulation or the greater number of such machines that would be manufactured.

After United's original purchase was made and the full-task, specific-type flight simulators were in service, it was found that a great many more fields of instruction could be covered advantageously and economically by the simulators than had originally been anticipated. A study was made to determine the desirability of a part-task simulator in order to relieve the whole-task machine of much of this sort of instruction. For instance, consideration was given to the purchase of a modification of the DC-6B simulator, especially designed for the instruction of flight engineers.

It is possible that, with the purchase of several such machines, some economy could have been experienced; but, in the special case studied, the availability of exact duplicates of the original machines at moderate cost (because engineering had been paid for) made it more economical to get the full-task simulator. The additional flexibility so gained was also thought to be of considerable merit.

The generalized type of simulator, representative of a "class" of airplanes, was rejected early in the day,

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* Director of Training, Flight Operations.

and nothing in the experience has revived it. Rather, even the full electronic flight proficiency type of trainer has lost ground at United, and the old-type Link trainer has taken a new lease on life. A dozen of them are being modernized and brought up to date.

United's experience has confirmed the original opinion that the simulation as far as possible of flight characteristics and feel is important; furthermore, that the simulator must be maintained to ensure continued verity in the simulation and conformance to the flight characteristics and must be modified along with the fleet it represents.[1]

The question of safety has many answers, and experience indicates that no one of them is the full and complete solution to the problem. Unquestionably one of the major safety means in air transportation is for a fully qualified, experienced captain to be in charge of the airplane. This professional pilot must, as the term implies, know his business throughout its full range, including his route, airports and Nav-Aids, his equipment, the deficiencies that are inherent in all of it and the means to overcome them, together with excellent judgment. The latter can come and be evaluated only from experience.

The safety of the operation is dependent upon the application of all of this to the completion of the flight by the captain in a safe, comfortable, efficient manner. It is obvious that the air carrier industry has adopted this premise without equivocation. It is in the details of qualifying the personnel that differences of opinion prevail.

The mere adoption, however, of simulators is not in itself sufficient. They must be utilized effectively, and in order to achieve this, their special maintenance requirements must be understood and their inclusion in the training program must be made with a knowledge of their strengths and weaknesses.

In the preliminary studies made by United Air Lines on the utilization of the simulator, it soon became apparent that a great deal of the value of the machines in the training program would depend upon the basic organizational, training, and maintenance policy that was adopted. The experience of Pan American with their Boeing 377 simulator, then at New York, and that of the British Overseas Airways Corporation's similar type in London, as well as military experience, was drawn upon in this study.

It was recognized that there would be two distinct types of flight officer training in the simulator—the proficiency training which involved the line crews actually in schedule would be an addition to anything that was then being done, while that which involved basic transitional or upgrading training would be a substitute to some degree for the flying equipment itself.

Accordingly, the plan adopted for transition training utilized the simulator much as an airplane, with the flight and flight engineer instructors using it in the same capacity as they were used in the aircraft. In other words, the simulator replaced the airplane in part. In the case of the line crews, a new instructor—the Flight Simulator Instructor—came into being, and the ranks have been filled from pilots who have had considerable line flying experience.

Another important innovation was adopted. In the qualification of an individual in basic transition or upgrading training, it is of course essential and in keeping with the regulatory requirements of the CAA that grades be assigned in accordance with the quality of the work and to the end that there be a record that the individual has satisfactorily completed his rating. In the periodic proficiency training of line crews, it was decided that far more value would accrue if the marking of the individuals or the crews as a whole was eliminated. In other words, they receive training until the standard is satisfied. This has proved to be one of the strongest features of this phase of the program.

The instructor is able to meet with his crew not as a checker but on a basis of complete confidence, and the weaknesses, if any, of the individual can be worked on without his feeling that it is a showdown that will be held against him. Not only has this approach proved to be of enormous value in the selling of the line crews on the simulator program, but it has resulted in a marked improvement in intracockpit relations, crew organization, and standardization of the individuals. It must be remembered that labor contract requirements and crew assignment practices preclude the keeping together of a flight crew for extended periods, emphasizing thereby the necessity for as much standardization of functions as possible.

The simulator operator, whose job at United is confined to the operation of the Nav-Aids and the keeping up of the simulated tower and ATC communications, is a promoted Link Trainer Operator with additional training to upgrade him to the more complex job involved with the flight simulator. He works completely under the instruction of the Flight Simulator Instructor who is the one responsible for the training session.

Maintenance of the simulator was accepted as being different from the maintenance of anything else on the line. Accordingly, qualified electronic technicians were specially trained for the job and are assigned full time.

Together with the programming of the progressive maintenance system, a project control was established under the direction of an electronics engineer to ensure that the simulators are modified and the projects completed, keeping them up with the changes and modifications being made to the fleet. Each adopted project for fleet improvement is studied to determine whether it should be included into the simulator as a project. Obviously those things that do not affect the cockpit or the controls, such as cabin changes, etc., receive no further consideration. A project, however, that involves new items of control—pitch angles of propellers, for instance, or the installation of a new item, such as the Martin bar in the DC-6 or other cockpit features—must be completed in the simulator along with the work on the fleet. It has been found that some proposed projects for the airplane can best be installed first in the simulator for test and verification. By this procedure,

deficiencies have been found and improvements made in a most economical manner.

The overall effectiveness of the organization is indicated by the completion of 16,500 hours of simulator instruction as of October 31, 1955, including the period of several months during which the training of personnel to instruct, operate, and maintain the simulators was done. This comprised a total of 74 simulator months with four machines, the first two having been put into service in February, 1954. The overall utilization during this period is 223 hours per month per simulator. Naturally as familiarity with the simulator and its application increased, the training utilization increased substantially as well. One problem that delayed things materially was with the pilot labor contract. During this past year, the average utilization exceeded 300 hours per month per simulator, and for several months the one CV-340 simulator used extensively in basic and transitional flight training averaged over 400 hours a month, reaching a peak of 469.

One of the first questions invariably asked about the simulator pertains to the size of the fleet necessary to justify its purchase. Justification for such a machine can be either in the field of better trained flight personnel or in that of economics. In the former case and considering that safety is of paramount importance, it can be said that, when the airplane is an extremely exacting type requiring the full attention on the part of its crew members, especially during instrument approach procedures or on take-off with the potential of an emergency, the simulator is essential for full training regardless of the size of the fleet. This is because the crews cannot be trained in all emergency procedures in the airplane alone, nor can a full appreciation of the need for crew specialization in certain configurations be gained other than in the simulator. In other words, the simulator does training, *essential* training, that under no circumstances can be performed in the airplane itself.[2]

In considering the economic justification of simulators and the ratio with the airplane fleet, there are too many variables to allow a rigid ratio to be expressed. These things are all taken into account in the development of the economic justification of the flight simulator on United Air Lines which follows.

The various types of training taken more or less in the order in which they apply to a flight officer or a crew and the savings applied to the established and approved curricula which are possible with the simulator in comparison to the use of the airplane alone are found in the several diagrams. It must be realized that while it is generally considered that these comparisons are based on an equivalent amount of training—airplane alone versus airplane and simulator—no such comparison actually is possible. This is because so much more in the way of crew and emergency training can be given in the simulator than is possible in the airplane.

In establishing the curricula and the comparisons between the use of the airplane alone and the combination of the airplane and the simulator, every attempt was made to be consistent.

The DC-3 airplane was the first for which a CAA-approved training program was required. This was during the middle to late Thirties, and the per capita cost of flight crew member training per annum was about $700. The costs have increased steadily, rising rapidly after the close of the war to approximately three times that figure about 1950. As a general support for the spectacular savings to be noted, as well as the equally spectacular gains shown on the accompanying charts, it can now be said that the per capita cost has leveled out while the quality of the training and of the resulting product has continued to improve at a substantial rate.

Fig. 1 shows a comparison of the basic Flight Engineer-First Officer training for the year 1956. Note that the direct savings amount to $876,000 and that credit of $716,000 is taken for potential earnings of airplanes that would otherwise be tied up in training. These gains are net for, in computing the saving of airplane time, the actual out-of-pocket costs of the airplane have been used, offset by the total costs of the simulator. In estimating the potential gains, only full-time assignment of airplanes for training purposes has been taken into account, and against the gross earnings the estimated direct costs of operation have been used as an offset. In addition to this, since such returns would directly be added to the profits, the profits tax has been deducted. It is noted that the savings and gain total $1,592,000 for the basic training course for 240 trainees, the 1956 estimated load. It must be noted here, however, that at no time have new trainees been put through the CV-340 qualification without the simulator. All preceding trainees had been DC-3 qualified first. The airplane alone time is an estimate accordingly.

Fig. 2 shows the upgrading training worked out on a basis similar to that for Fig. 1. Currently upgrading training is being given in the DC-3 airplane. This type of training not only is an obligation in the labor contract but has been found to be extremely valuable in determining the command potentialities of the copilot of some experience. It is given just before the expiration of 3 years after assignment as a copilot. The use of the Convair 340 in this type of training is new this year. Since it is one more step and could have been the ultimate step in the elimination of the DC-3 type of airplane from the operation, there are some savings that might have been taken into account because one type of airplane will be eliminated from the fleet. This has not been done. It is to be noted in this chart that the potential gains are rather low because the average earnings of this type of airplane are definitely lower than those of the four-engined type, largely because of a considerably lower utilization. The number of trainees involved, 240, is the estimated number for 1956.

Fig. 3 shows the cost of transition training for the CV-340 airplane, estimating that 20 crews will be so trained during the year. The savings here are not spectacular,

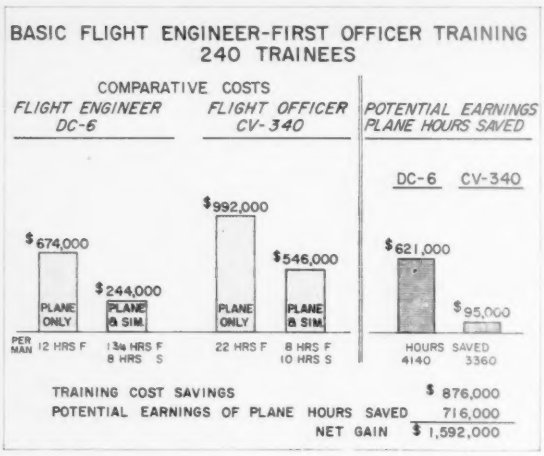

FIG. 1.

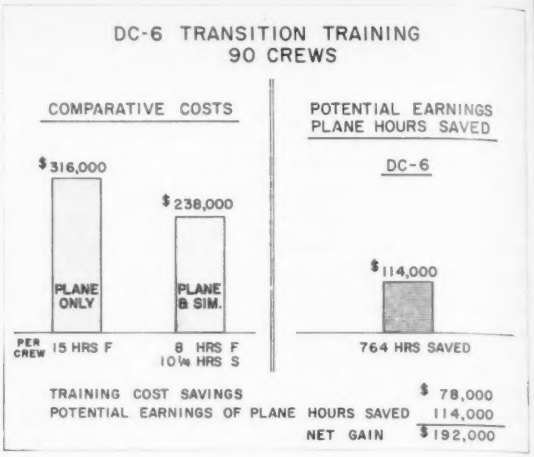

FIG. 4.

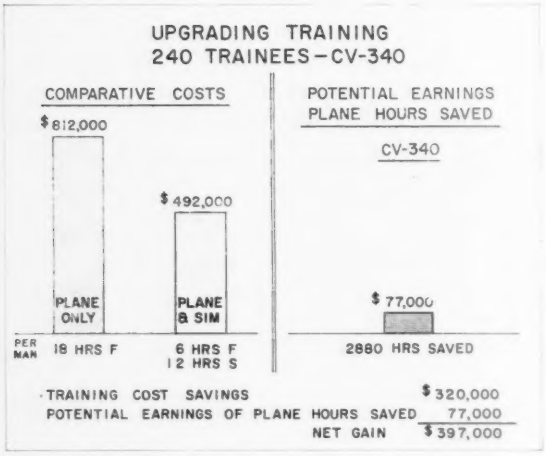

FIG. 2.

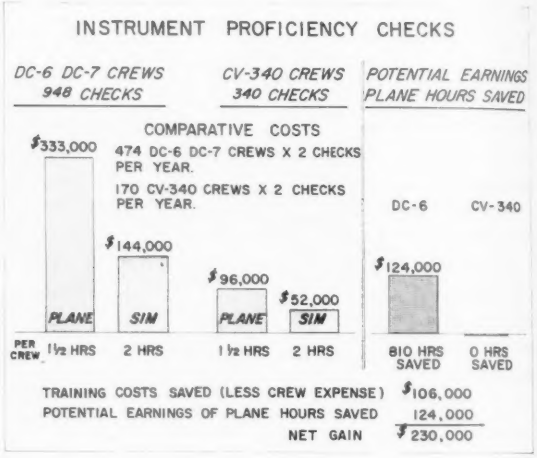

FIG. 5.

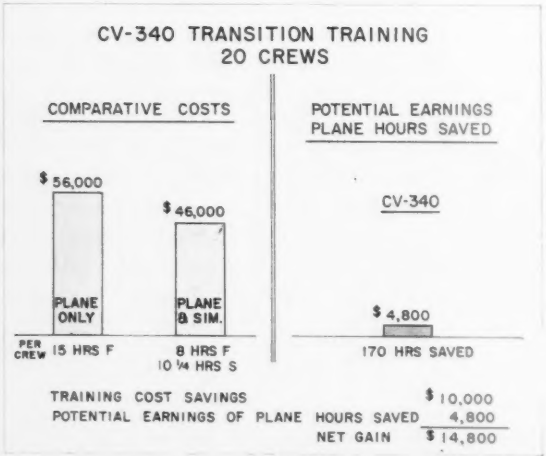

FIG. 3.

SUMMARY OF ECONOMIC GAINS BY USE OF SIMULATORS 1956 TRAINING PROGRAM

	TRAINING COST SAVINGS	EARNING POTENTIAL OF PLANE HRS. SAVED
BASIC FLT. ENGINEER-FIRST OFFICER	$876,000	$716,000
UPGRADING	320,000	77,000
DC-6 TRANSITION	78,000	114,000
CV-340 TRANSITION	10,000	4,800
INSTRUMENT PROFICIENCY CHECKS	106,000	124,000
TOTALS	$1,390,000	$1,035,800
COMBINED GAINS (ABOVE)		$2,425,800
LESS PAY AND EXPENSES OF 644 DC-6, DC-7, CV-340 CREWS DURING FOUR DAYS (16 HRS) OF REFRESHER TRAINING IN SIMULATORS		$ 254,000
NET ECONOMIC GAIN		$2,171,800

INVESTMENT IN SIMULATORS AND FACILITIES THROUGH 1956 – $5,275,000

FIG. 6.

largely because the great mass of training for this type of airplane has been completed and all new employees have been for the past year and will be in the future given their basic training in it.

Fig. 4 shows the transition training of the DC-6 type of airplane, estimating 90 crews. The estimate was made on the same basis as the preceding figures.

Fig. 5 takes into account the costs of giving proficiency checks in the simulator in comparison to the cost in the airplane. This is a forecast figure, for the CAB has not as yet approved the procedure. Application for a change of regulation is about to be made. The basis of estimate is quite similar to the preceding figures except that the crew expenses involved in bringing the crews to the two Training Centers, Denver and Chicago, have been taken into account. The proficiency check in the airplane has ordinarily been given at the domicile without pay or expense. It is to be noted also that no credit for potential earnings is taken on the CV-340 airplane. Again because of the low average hours of this type, no difficulty has been experienced in getting airplanes for check purposes. The contrary is true with the DC-6 where it has been necessary to assign an airplane for several months each year, rotating it among the various domiciles twice a year. Credit is here taken on the basis outlined earlier.

Beginning the middle of this year, it is planned to give in connection with the semiannual proficiency checks an additional 16 hours of simulator instruction. In other words, each year two periods of 10 hours will be given to each crew which will include two 2-hour proficiency checks in the simulator. The cost of this additional training has been taken into the total figures shown in Fig. 6, a tabulation summing up these various gains. This estimate includes the crew expenses and salary for compensatory time off.

Earlier it was mentioned that a DC-8 simulator was under consideration. It will be on order shortly. Since a flight simulator specifically represents a given airplane, there is some hazard in ordering a simulator to be available before the airplane has been built and test flown. The advantages of having a simulator preliminary to the airplane, however, are so great, especially for an airplane that costs in excess of $5,000,000, that this risk will be taken. It is expected that the simulator will be in operation about a year before the first training airplane. A large part of the ability to embark on this program is due to the fact that the Douglas Aircraft Company, Inc., has available in great detail the expected performance of their airplane, and the experience with their production has been so good as to indicate that, while modification of the simulator will be needed to some extent when the actual test data become available, it is not expected that the costs will be so great as to offset the potential savings and great value in training that would be lost if purchase of the simulator were delayed.

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AERONAUTICAL ENGINEERING REVIEW

Excluding confidential sessions, a total of 17 technical papers were presented at the IAS National Summer Meeting, June 18–21 in Los Angeles.* For the summary of these papers, the Institute and REVIEW are indebted to the various coordinators. Their reports follow—ED.

A DIGEST OF SUMMER MEETING PAPERS

Aerodynamic Heating (Aerodynamic Aspects)

***Chairman*, Clark B. Millikan**
Director, Guggenheim Aeronautical Laboratory; Director, Southern California Cooperative Wind Tunnel, California Institute of Technology

Carl Gazley, Jr., Coordinator
Aerodynamicist, The RAND Corp.

The first paper of the morning session, "The Problem of Aerodynamic Heating," by E. R. van Driest, Research Specialist, of North American Aviation, Inc., considered the origin, as well as the consequences, of aerodynamic heating. Dr. van Driest reviewed the status of methods for predicting aerodynamic heating under various circumstances and indicated important areas for future research. He also presented some results of his own recent research on the effects of surface cooling in delaying boundary-layer transition.†

The second paper, "Surface-Protection and Cooling Systems for High-Speed Flight," by D. J. Masson and Carl Gazley, Jr., Aerodynamicists, The RAND Corporation, discussed problems associated with protecting surface structure and internal compartments from the effects of severe aerodynamic heating rates. Dr. Masson and Dr. Gazley considered systems for both transient and steady-state situations. It was determined that, for the lower speed range, the use of a thickened metallic skin is the most efficient means of countering the surface aerodynamic heating. In this range, cooling of internal equipment by ultimate dissipation to atmospheric air was held most feasible. For higher flight speeds, surface protection was determined to be best accomplished by insulation of the outer structure and internal cooling or by a transpiration or mass transfer system. Cooling of internal equipment in this range was held most efficiently accomplished by an expendable vaporizing coolant or by the thermal capacity of the equipment and structure themselves.

The last paper of the morning was "Experimental Hyperballistics," by H. H. Kurzweg and R. E. Wilson of the Naval Ordnance Laboratory, and was presented by Dr. Kurzweg. The paper dealt with experimental techniques for simulating full-scale flight conditions in the atmosphere. In addition to the effects of viscosity and compressibility, familiar at lower speeds, chemical effects become important at hypersonic speeds. The use of such experimental facilities as wind tunnels, shock tunnels, and aerodynamics ranges was discussed. The operation and advantages of light-gas guns as a model-launching device were described. Experimental results from several of the NOL facilities were given.

AS SUMMER MEETING BECAME AIR BORNE. Many were the huddles such as this as the Technical Sessions of the Institute got under way in Los Angeles in June. Several figures prominent in the first session, on Aerodynamic Heating (Aerodynamic Aspects), are pictured above. Shown standing around Clark B. Millikan, Session Chairman, are *(left to right)* H. H. Kurzweg, D. J. Masson, and E. R. van Driest, all of whom presented papers.

Aerodynamic Heating (Structural Aspects)

***Chairman*, William F. Ballhaus**
Chief Engineer, Northrop Aircraft, Inc.

Carl Gazley, Jr., Coordinator
Aerodynamicist, The RAND Corp.

The afternoon session started with the paper, "A Re-Evaluation of Some Air-Frame Thermal Problems," by Norris E. Dow, Structures Engineer, Special Defense Products Division, General Electric Company. Mr. Dow surveyed some of the aspects of elevated temperature structural

* The majority of these papers are being published in full in the REVIEW and are also available in preprint form (see p. 329 of the September issue).

† For the complete paper, see pp. 26–41 of this issue.

design and evaluated their relative importance. He considered such factors as thermal stresses, creep, and heat absorption and concluded that many of the second-order effects, neglected in first approximations, tend to be beneficial. Therefore, many of the problems may not be so serious as has been anticipated.

The paper, "Performance of Materials at Elevated Temperatures for Aircraft and Missile Application," by Alan V. Levy, Chief, Materials Group, Marquardt Aircraft Company, was withdrawn shortly before the meeting for security reasons, and Clyde W. King, of North American Aviation, Inc., kindly consented to present a paper on "The Creep Buckling of Aluminum-Alloy Plates at Elevated Temperature." This paper reported a series of creep-buckling tests on flat panels of the integral skin-stringer type of construction of 2024-T4 and 7075-T6 material. Each material was tested at four temperatures with stress levels selected to cause creep failures at times less than 200 hours. The results were correlated with the master rupture parameter to indicate the lifetime similarities for tension and compression failures. Design charts were presented for both 2024-T4 and 7075-T6 as constant times of buckling failure as a function of stress and temperature.

Lewis H. Abraham, Chief, Missiles Strength Group, Douglas Aircraft Company, Inc., discussed several methods of simulating aerodynamic heating of structures in his paper—last of the session—"Techniques and Problems in Testing Structures at Elevated Temperatures." It was pointed out that present experimental facilities do not allow simulation of the extremely high aerodynamic heating rates occurring for combinations of hypersonic speeds and low altitudes. Mr. Abraham stressed the importance of close simulation of the loading cycle, as well as aerodynamic heating. Unless the loading rates and times of application are closely approximated, the resulting test data can be excessively conservative, he pointed out.

Operation of Large Turbine-Powered Aircraft

***Chairman*, E. F. Burton**
Chief Engineer, Santa Monica Division, Douglas Aircraft Company, Inc.

C. R. Crantrell, Coordinator
Aerodynamicist, California Division, Lockheed Aircraft Corp.

This session was intended to convey some of the jet operational experience of the Strategic Air Command to the commercial air lines of the United States soon to commence introduction of turbine-powered aircraft fleets. Principal speaker was Col. Richard E. Evans, Deputy Director of Tactical Requirements, Headquarters, SAC. Prepared comments were delivered by W. E. Rhoades, Manager of Engineering, Flight Test, United Air Lines, Inc., and Sydney Serebrney, Chief Technical Meteorologist, Pacific Division, Pan American World Airways, Inc.

Colonel Evans' paper was entitled "Operational Aspects of the SAC Transition to Jets" and discussed the "growing pains" associated with the conversion from prop-driven to jet-powered fleets in the light of their application to the future operation of commercial jet and turboprop transports. Performance characteristics of the B-47 were used to illustrate the fundamental effects of turbine power on flight planning and clearance and on take-off, climb, cruise, and let-down and approach procedures. Winds and wind forecasting at jet altitudes were discussed, as were icing, turbulence, and the capabilities of radio and radar and their application to navigation and the airways' traffic control problem. Also reviewed were some of the characteristics of swept-wing aircraft and their effects on flying qualities and piloting techniques.

In discussing take-off characteristics, Colonel Evans made the point that a reliable indication of the airplane's actual acceleration is required early in the take-off run. The "critical field length" does not take into account adverse effects of reverse thrust, brake failure, blown tires, unusual runway surface condition, or pilot indecision at the "critical refusal speed." The requirement is for an accelerometer which will total all the variables which might adversely affect the take-off run and will give the pilot an early "go-no-go" presentation. (The NACA has developed such a device and is currently testing it on a SAC B-47.)

Except for winds, weather phenomena at jet altitudes are not significant, Colonel Evans stated. At jet operating altitudes, 50-knot winds are the order of the day, 100-knot winds are frequent, and 150-knot winds are routinely encountered. The SAC has learned to plot with acceptable accuracy the general wind pattern, but it is difficult to predict for a specific time the exact position of the jet streams, both laterally and vertically. For this reason, continuous checks are required on ground speed and course when operating near the jet streams, and mapping radar is considered an essential item of navigation equipment for modern, long-range jet aircraft.

Weather at destination and alternate airports takes on a new significance for jet aircraft, since it must be accurately forecast well in advance. SAC has solved this problem by setting up a UHF pilot-to-forecaster frequency and by requiring the forecaster to take continuous cognizance of the weather during periods when the ceiling or visibility is down to certain established levels.

As for the airways' traffic control problem, there is little or no delay in traffic under VFR conditions. A system is needed, Colonel Evans said, which would permit an airplane to clear "VFR" under instrument conditions—that is, put the air surveillance radar in the cockpit rather than in the traffic control tower. We are already well out on the learning curve for the development of a device to see through restrictions to visibility, and Colonel Evans stated that this development should be pushed.

Colonel Evans pointed out that the newer SAC bombers and the coming turbine-powered air liners will incorporate many advances over the first generation of jet aircraft which will make jet flying much simpler and safer. But commercial and military operators alike are still faced with one of the biggest problems of all—noise. Colonel Evans concluded that, if the air lines can solve this one, "flying the jets will be a breeze."

Mr. Rhoades, of United Air Lines, acknowledged in his remarks the great benefit to the commercial operators of the pioneering work done by the military. Mr. Rhoades went on to point out, however, that the air lines are out to make money, and this consideration affects the best solutions to the turbine-powered aircraft operational problems, from the commercial as opposed to the military viewpoint.

To fulfill their schedules with acceptable regularity, the air lines must be equipped to operate consistently under generally lower weather minimums. Also, to avoid passenger inconvenience by diverting to alternate destinations, the commercial transports will hold at lower altitudes and in greater traffic congestion. Because their mission is not primarily a long-range one, the commercial operators find their optimum economics at lower cruise altitudes: in the order of 28,000 ft. for domestic route structures, with 35,000 ft. as a maximum altitude for some time to come. These considerations will affect the severity of icing problems, reserve fuel allowances, visual aids at airports and in the cockpit, weather minimums, descent procedures, and the airways' traffic control problem.

Mr. Serebrney, of Pacific Division, Pan American World Airways, in commenting on Colonel Evans' paper, made the point that, with their new high-speed, high-altitude turbine equipment, the air lines stand to make or lose a lot of money

from the winds—the jet streams. As noted by Colonel Evans, we are not yet able to predict the jet streams with acceptable accuracy. Mr. Serebrney said that there are two kinds of jet streams known to Pan American pilots: the ones that are tailwinds, and those "blankety-blank jet streams of the forecaster's."

Although the general pattern of the jet streams' flow around the world is known, it is in their precise forecasting for specific periods that much remains to be done. That the streams can vary markedly and unexpectedly over short periods of time and space, in both velocity and direction, was cited by Mr. Serebrney with examples from the flight logs of a BOAC Comet flying between Tokyo and Hong Kong.

Pan American flights have obtained wind and outside air temperature data at 10-min. intervals when operating near the jet streams; the data show a definite correlation, but the trend of velocity change with temperature change can be reversed under differing atmospheric conditions, within small geographic regions. It is in this area that a great deal of research must be done, and much will be done by the commercial operators.

Since the winds at altitude are a potential source of great economic gain or loss, Mr. Serebrney concluded, their proper utilization is one of the most challenging operational problems of the commercial jet age.

Low-Speed Flight

***Chairman*, Jim Hong**
Aerodynamics Division Engineer, Lockheed Aircraft Corp.

C. R. Cantrell, Coordinator
Aerodynamicist, California Division, Lockheed Aircraft Corp.

The Low-Speed Flight session was included in the 1956 National Summer Meeting to focus attention on an area of aeronautical development which is easily overlooked at a time when such great progress is being made at the high end of the flight speed regime. Attention was devoted principally to recent developments in STOL and VTOL aircraft, and the session included papers by representatives of the aircraft industry, the U.S. Army, and an academic research institution.

The scheduled chairman of the session, Philip Colman, of Lockheed Aircraft Corporation, was unable to attend, and his place was ably filled by Jim Hong, Aerodynamics Division Engineer at the California Division of Lockheed. In his opening remarks, Mr. Hong noted that the dream of aircraft designers has long been to produce an "everyman's airplane" and that the backyard operational requirements of such an aircraft might well be solved by the true VTOL type. This adds even more emphasis to the already great possibilities of the STOL and VTOL types with high-speed capabilities for military and commercial applications.

The first paper was "VTOL Fixed-Wing Aircraft," by Ken S. Coward, Preliminary Design Engineer, Ryan Aeronautical Company. It was presented by Mr. Coward and stressed the fact that fixed-wing vertical take-off aircraft demonstrate the vertical operation capability of the helicopter while retaining the speed and altitude advantages of the airplane. The spectrum of the VTOL fixed-wing types includes tail setters, ducted propellers (flying platforms), tilt engine, tilt wing (tilt fuselage), and deflected slipstream. Mr. Coward briefly discussed each type and reviewed basic physical considerations involved in the development of static thrust and lifting and hovering ability.

Aside from their jet VTOL design, the Ryan Aeronautical Company has concentrated on the deflected slipstream principle. Mr. Coward described some recent development work done at Ryan, including full-scale testing of the deflected slipstream principle to verify the model work performed by the NACA. Tests of a wing, engine, and propeller combination showed the slipstream to be deflected through a range of angles from approximately 61 to 75 deg. The complement of this angle is that through which the airplane must be tilted to accomplish a vertical take-off.

Ryan has also conducted tests to determine the effect of reducing propeller blade twist, beneficial for static thrust, on the propulsive efficiency in forward, cruising flight. Speed-power flight tests were run on a standard propeller for the Navion airplane and on a propeller with one half of the original twist. The tests indicated no noticeable difference in propulsive efficiency resulting from untwisting the propeller. There was evidence that the climb performance was actually improved by the untwisting process. Thus it appears that propeller twist, long held sacred by propeller designers, can be varied to increase static thrust for STOL or VTOL operation without serious effect on level-flight, cruise efficiency. Mr. Coward made the point that increased experimental work should be devoted to increasing propeller static thrust.

Mr. Coward concluded that the fixed-wing propeller types utilizing the deflected slipstream principle for VTOL capability are feasible and briefly discussed the attendant problems of power-plant failure during take-off and stability and control in the critical hovering and transition phases of flight. There are many avenues open to the solution of these problems, and pay-load - range analyses of the type lead to the conclusion that the possibilities for a truly universal aircraft are tremendous and that it will soon be a reality.

The second paper, "STOL and VTOL Aircraft in the Air Mobile Army," was prepared and presented by Lt. Col. Michael J. Strok, Project Officer in the Aircraft and Electronics Division, Office of the Chief of Research and Development, Department of the Army. Colonel Strok defined the combat mission of the Army, described how the airplane fits into that mission, and indicated how the mission dictates the operational and logistic characteristics of the acceptable Army air vehicle.

The airplane, in its many forms, must fulfill four broad mission areas in the combat Army: battle area mobility, observation and reconnaissance, artillery fire control, and battle area rescue and evacuation. These missions must be fulfilled independently of environment and terrain—i.e., without dependence upon prepared take-off and landing areas. Since the Army airplane must live and operate under round-the-clock combat conditions, it must be simple and easy to maintain and must possess a high degree of reliability. Colonel Strok made the point that, although economy of operation is of great importance in combat areas, from the military customer's viewpoint the primary consideration must be reliability and maintainability. In the expanded battle areas typical of atomic-age warfare, the Army airplane must also possess the pay-load, speed, and range capabilities typical of the efficient, fixed-wing aircraft.

With the Army combat mission dictating the operational and logistic requirements, Colonel Strok defined the adequate Army air vehicle as a wide speed range aircraft with STOL and VTOL performance. The choice of STOL or VTOL will be largely determined by the specific mission application. At the present time, a STOL aircraft may be defined as one with 500-ft. take-off and landing capabilities over a 50-ft. obstacle when operating from unprepared terrain under NACA standard conditions, as the minimum acceptable for most missions. A true VTOL capability is required for certain specialized missions within the four broad mission areas previously discussed.

The helicopter has become an essential item of Army equipment, and continued development effort is under way to increase its pay load, range, speed, reliability, and maintainability with lower initial and operating costs. New VTOL aircraft, however, with the greater capabilities of the efficient, fixed-wing design, may well give the latter type a decisive advantage within the next several years. Colonel Strok drew the conclusion that the Army's helicopter experience should be used as a guide not only for the design and

manufacture of new helicopters but particularly for practical STOL and VTOL designs for both military and civil use.

Colonel Strok suggested several research and development areas essential to the realization of practical STOL and VTOL designs that will fulfill the requirements of the Army combat air vehicle. Among these are basic research and development to improve gas-turbine engine power-to-weight ratios and fuel specifics and to increase simplicity of control. Increases in propulsive efficiency over the entire flight speed range, particularly static efficiency of propellers for some of the VTOL types, are necessary. Ducted propellers or fans as a means of increasing static thrust require more investigation to understand the mechanism of airflow and thrust generation. Maximum flotation, high-energy-absorption landing gears are a necessity yet to be achieved. Boundary-layer control systems offer encouraging possibilities for achieving practical slow-speed, vertical-lift aircraft.

The potential of practical STOL and VTOL aircraft in civil as well as military use, Colonel Strok concluded, is sufficiently great that it offers a real development challenge to all in industry who recognize the opportunity.

The third and final paper was entitled "Lift on a Wing in a Propeller Slipstream as Related to Low-Speed Flight" and was prepared and presented by Scott Rethorst, a recent graduate student in Aeronautics at the California Institute of Technology. Dr. Rethorst's paper presented an analytical solution for the lift of a wing in a propeller slipstream which agrees closely with experimental data. Since no previous theory has adequately predicted the lift of wing-slipstream combinations, this method should provide an important contribution in this area. It is of particular importance, of course, in the low-speed flight regime of STOL and VTOL aircraft.

Dr. Rethorst's paper was based upon his Ph.D. thesis, recently completed at Caltech, and a complete mathematical treatment is being offered to the JOURNAL OF THE AERONAUTICAL SCIENCES for publication. The present paper* presented a description of the problem, an outline of the method of attack, a comparison with experiment of the theoretical results obtained, and an indication of how the results may be applied to design.

Previous solutions for the lift of wings in propeller slipstreams have been based on lifting line and slender body theory, and the two results bracketed the experimental data. Dr. Rethorst's method utilizes lifting surface theory to calculate the downwash at all points in space caused by the combined wing-slipstream flow fields. The downwash values may then be inserted into a suitable lifting surface theory, such as that of Weissinger, to obtain the final results, which are the magnitude and distribution of the lift of the wing-slipstream combination. The method also provides the values of downwash in the regions of tail surfaces and thus contributes toward the handling of the critical stability and control problems in STOL and VTOL configurations.

The results presented in Dr. Rethorst's paper may be applied to design at the present time. Data are already programmed for the IBM Type-701 calculating equipment which will provide values of downwash anywhere in space caused by a given wing-slipstream configuration, at all slipstream velocity ratios. A detailed outline of the application of the method to design will be included in the paper being offered for publication.

Perhaps the greatest contribution of this method, however, is that the availability of an analytical solution now permits the employment of optimization techniques so that the wing-slipstream geometry which will provide the greatest lift, or the optimum STOL characteristics, may be determined as a function of general design parameters, such as wing loading and power loading. These techniques should appreciably strengthen our attack on the problems of low-speed flight.

* See pp. 42–48 of this issue.

Economics

***Chairman*, L. E. Root**
Director, Development Planning, Lockheed Aircraft Corp.

Frederick H. Green, Coordinator
AiResearch Manufacturing Co., Division of The Garrett Corp.

The general economic outlook for the aircraft industry is good, although brief periods of adjustment may occur and a certain amount of uncertainty of necessity will continue as an ingredient in the recipe for continued growth.

That appeared to be the consensus of three papers presented at the Economics session. Titles were "An Economist Looks at the Aircraft Industry," by George A. Steiner, Senior Economic Adviser, Development Planning, Lockheed Aircraft Corp.; "Air Force Logistics—Some Recent Developments," by Allen R. Ferguson, Acting Chief, Logistics Branch, The RAND Corp.; and "Passenger Air Line Economics," by Lloyd B. Aschenbeck, Route Study Engineer, Douglas Aircraft Company, Inc.

Mr. Steiner foresaw two major economic developments likely to be of importance to the aircraft industry over the next 10 to 20 years: (1) the level and stability of national economic activity, where the long-range outlook is for a rising Gross National Product with no major depressions or price inflations; and (2) the way the East-West conflict is reflected in federal aircraft expenditures, where no important reduction of defense efforts is foreseen.

Mr. Steiner said that the two trends indicate that individual corporations may look forward to more stable growth with demand for products relatively high and reasonably steady for many years in the future. Comparatively high level and stable demand, he said, also may generate stiffer competition.

The speaker forecast that the military will be more cost-conscious, which may take the form of increased competition in procurement, a movement toward more fixed-price contracts, the extraction of more performance guarantees, stricter and less liberal facility contracts, and other methods to control better costs of military equipment.

Commercial customers, too, he said, will be more concerned about costs in the future, observing that, in the transport area, service costs are not so important as rising population and national income in lifting demand. He warned, however, that if service costs are to fall to the point where important inroads are to be made upon travel by passenger automobiles, particularly in the shorter hauls, cost of equipment per passenger-mile must drop sharply.

Mr. Steiner also saw pressures for reduced costs springing from company managements. He said that productivity of the nation's manpower is rising, and one can expect that wage rates, particularly in the mass production industries, will at least reflect these gains in productivity. "In the future, as in the past," Mr. Steiner said, "such wage-rate increases will reflect in collective bargaining in the air-frame industry. If management of the air-frame industry does not match these wage-rate increases with increased productivity, the price of airplanes will for this reason alone rise while the comparable price of competing means of transport remains constant or falls."

The recent developments discussed in the Ferguson paper were steps necessary for the logistics system to perform its function in the environment of the early 1960's—the introduction of improved logistics policies, the role of airlift, and the maintenance of control over Air Force assets.

Mr. Ferguson forecast that the decade, for the Air Force, will be one of great technical complexity and of military uncertainty and risk. The logistics system, he said, will have

to support both manned aircraft and unmanned missiles in large numbers and hundreds of remotely located radar sites, It must be ready, he warned, to support any of many kinds of war.

The paper continues with a discussion of the requirements that the various kinds of possible wars throw upon the combat elements of the Air Force and logistics. Mr. Ferguson cautioned that the assumption must be that any day can be D-Day—meaning that the logistics system has to be in being and ready in peacetime and that a maximum of the aircraft in the inventory should be combat-ready at all times.

Regarding new logistics policies, Mr. Ferguson said that research is under way on such problems as whether it is more economical to buy additional logistics support to reduce the number of aircraft out of commission while undergoing or awaiting modification, repair, or supply, or whether it would be more economical to purchase more aircraft to have the desired number of planes combat-ready.

Mr. Ferguson's paper described the revision of logistics data processing as a major development of great importance in meeting the operational needs of the 1960's. He asserted that business data processing machines have made available to logistics these new capabilities: great speed of computation, great capacity for storing information, rapid access to stored information, and high accuracy.

The paper also tells of a new system which is under development by the Air Material Command with technical assistance from The RAND Corporation and which has as its core data processing centers linked by appropriate communication nets to the bases, storage depots, various command organizations, and contractors. The following is an example of the efficiency of this system: Once a part is issued, a single punch card would be prepared at the using base and fed into the computer at the center which would automatically reduce the recorded inventory of that part, compare the new balance with the resupply level, and—if the base now had "too few" of that part—the machine would check the stocks available at the storage depots or at bases with relative surpluses. Then, in accordance with the rules prescribed, the machine would prepare and transmit a shipping order directing a shipment of that part to that base from an appropriate source.

The Aschenbeck paper analyzed passenger air-line economics, using for demonstration the problem of traffic forecasting. The transportation industry was considered in its place in the economic background of the entire country. A chart of the American economy, showing where the money came from (Gross National Product) and how it was spent, pointed out that in 1954 approximately 9 cents of each National Income Dollar was spent on travel. It was also shown not only that air-line travel is competing with other travel mediums but that travel is competing also with other industries.

Mr. Aschenbeck estimated that by 1960 air will account for nearly 50 per cent of total United States common carrier travel—55 per cent in 1965. It is asserted that the air lines have made sufficient aircraft purchases today so that by 1960 they will have the equipment available to handle most of the market potentials. But, after a demonstration of the method of predicting the demand for air travel in terms of "seat miles," it was shown that the demand will exceed supply by 1965.

The basic economy of the various regions served by the air lines was listed as another factor in the problem of traffic forecasting. Large shifts in population, as well as the increase in population and in the new industries springing up, are described as having a tremendous effect on the changing economics of a given marketing area.

Sociological Influences of Aviation

***Chairman*, Robert E. Gross**
President and Chairman of the Board, Lockheed Aircraft Corp.

Frederick H. Green, Coordinator
AiResearch Manufacturing Co., Division of The Garrett Corp.

The first paper of this session, "Aviation: Enhancement of the Political and Cultural Stature of Man," by Bruce Campbell Hopper, Professor of Transportation, Harvard University, described man as an air animal, with a trail of evolution from the habitat of land folk through sea folk to air folk. Enlargement of his mobility dictates new concepts of existence.

For instance, in world politics, acceleration of the international exchange of peoples and goods spreads the contagion of free self-government. Rapid facilities for consultation by ministers of state and effective sharing of technological advance—tools and weapons—lessen the possibility of war by reducing fear to a more manageable scale. As a result, man, as a political animal, may move to the first task of the air age—making the planet viable.

The paper held that competitive coexistence, and the rivalry to hasten imperative adjustments to remedy the law of uneven development of nations, makes possible unprecedented advances toward the sublimation of war instincts to the general cause of further conquest of the forces of nature and of man in society. Therefore, the paper concluded, man—as a reasoning animal—may move to the second task of the air age. This is described as "controlling his own destiny."

In consequence, the adaptation of new concepts to new capacities creates the requirement of a working balance between man's know-how and his know-why—between the technical and the spiritual man. The result of the quest might well be formulation of a new moral philosophy to give man an invisible means of support as he acquires a new dimension, a longer vision, and a new personality with a larger soul.

The second paper in this session was "The Economic Impact of Air Transportation," by George P. Baker, Professor of Transportation, Harvard Graduate School of Business Administration, and President, Transportation Association of America. It first treated the subject of air transportation in terms of its impact as a purchaser of goods and labor and traced the history of the industry from a state of Government dependency to one of almost complete self-sufficiency over a limited period of years. Although the rate of growth is a most striking feature, the impact of the industry on the total economy as a purchaser of goods and services was not considered one of its notable characteristics.

However, the impact of air transportation as a producer of transport of various kinds was felt to have been most significant. Figures were given which show the terrific inroads made on the intercity public carrier passenger-miles by the air lines. Reasons why the air lines have barely made a dent in the vast short-haul intercity market of trips of less than 250 miles were given as follows: the time it takes to travel over congested highways between city and airport, the desire to have a car at destination, the disregard of cost when people choose between the use of automobile and other modes of travel, and the ease—in spite of all the criticism—of most commuter travel by rail.

The impact of air transportation as both a domestic and an international carrier has been primarily in its role as a carrier of passengers. As a hauler of freight, its impact has been inconsequential in terms of ton-miles handled in comparison with other forms of transport. The author feels that the future development of air cargo will center around the slow realization by businessmen that their distribution costs should be considered as a package and that transport cost is

only one part of this package which includes the costs of transporting, of warehousing, and of inventory.

The paper concluded with a discussion of the impact of air transportation on the ways of doing business in our economy. The airplane has brought about some striking changes in the manner of running a business. With its speed, industries can decentralize physical properties and maintain closely centralized management control at the same time. Executives can keep in even closer touch with developments within both their own company and their industry as well. It is felt that the ability to spread the most able people over a broader business area must have some definite plus effect on the ability of the nation to combine land, labor, and capital more efficiently in the production of goods and services.

Advanced Techniques

***Chairman*, Milton U. Clauser**
Director, Aeronautical Research Laboratory, The Ramo-Wooldridge Corp.

D. D. Warner, Coordinator
Northrop Aircraft, Inc.

This session was opened by Dr. Clauser with a brief discussion of progress made in nuclear power plants and of problems confronting industry in the design of suitable shielding. He then introduced A. P. Fraas, Principal Design Engineer, Oak Ridge National Laboratory, who presented a paper on "Aircraft Design Considerations Associated with Shielding for Aircraft Nuclear Power Plants." Mr. Fraas described problems of designing a shield for an atomic power plant to limit radiation to a safe level for aircraft applications. He covered the requirements for shielding materials and their ability to absorb the principal types of radiation. He concluded with a typical example of the weight of shielding required for a small nuclear power plant.*

The second paper was presented by William M. Kauffman, Aeronautical Research Scientist, of the NACA Ames Aeronautical Laboratory, on "Flight Application of Target-Simulator Principles." Mr. Kauffman covered the principal applications of target simulators to the flight testing of military aircraft. They included an air-borne target simulator for use with an optical gunsight, an air-borne target simulator for use with an oscilloscope-presentation fire control system, conversion of the original optical target simulator to represent a drone aircraft under the control of the pilot, and application of maneuver programing and display features to operational instrument flight problems.

Prepared comments were given by John Cummins, General Supervisor of Fire Control Radar, Northrop Aircraft, Inc., who brought out a need for inserting the target signal at a point in the system where a maximum number of the fire control system modules would be checked out.

* For the complete paper, see pp. 39–43 of the September issue.

Sherman M. Fairchild Publication Fund Papers

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286	Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours—Charles E. Mack, Jr., and Ignace I. Kolodner.	0.75	1.25
244	Wetted Area and Center of Pressure of Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
229	Wave Profile of a Vee-Planing Surface, Including Test Data on a 30° Deadrise Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
170	Wave Contours in the Wake of a 10° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Institute of Technology.	0.75	1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface—Experimental Towing Tank, Stevens Institute of Technology.	0.75	1.00
166	An Analysis of the Fluid Flow in the Spray Root and Wake Regions of Flat Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	1.20	1.60
165	Theory and Practice of Sandwich Construction in Aircraft (A Symposium).	1.85	2.50
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman.	0.75	1.00
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	0.35	0.50
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Mack, Jr.	1.85	2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	0.60	0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	2.65	3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	0.75	1.00

Papers should be ordered by number from: **Publications Dept., I.A.S., Inc., 2 East 64th St., N.Y. 21, N.Y.**

IAS News

(*Continued from page 23*)

Donald W. Richardson (M) has joined the Hughes Aircraft Company, Culver City, Calif., as a Research Engineer. He formerly was associated with the Curtiss-Wright Corporation, Propeller Division, Caldwell, N.J., as Assistant Project Engineer.

Earl R. Ryder (TM) has joined the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation** has formed a new subsidiary, Aerojet-General Nucleonics, in Walnut Creek, Calif. In charge will be Arthur T. Biehl and Robert Mainhardt, directors and officers of the new corporation.

• **Allison Division, General Motors Corporation . . .** Norman E. Eggers has been named Assistant Manager—Commercial Aircraft Sales.

• **Aluminum Company of America** has made available to industry a new 176-page reference volume, the *Alcoa Aluminum Handbook*, which is obtainable by writing to the company at 781 Alcoa Building, Pittsburgh 19, Pa. . . . The Sales Development Division, in cooperation with the Special Products Division, American Motors Corporation, reports that a new engine in whose design it assisted, weighs but 200 lbs. (carrying 70 lbs. of finished aluminum) and develops 62 hp.

• **American Airlines, Inc.,** reports it soon will start construction of the first school in the United States devoted exclusively to the training of air-line stewardesses. It will be between Dallas and Fort Worth, Tex., and will be equipped to train 1,000 students yearly. . . . Joseph V. Dooley has been elected Assistant Vice-President—Operations. . . . A vice-president has been named for the first time to head the air-freight department. He is Samuel C. Dunlap, Vice-President—Cargo (mail-express-freight).

• **Arma, a Division of American Bosch Arma Corporation,** has confirmed that it is participating in the Ballistic Missile Program as a principal contractor. The program includes two intercontinental ballistic missiles know as "Atlas" and "Titian," as well as an intermediate-range ballistic missile called "Thor." All are capable of carrying atomic warheads.

• **Avien, Incorporated,** has named Alfred Sansonetti Manufacturing Manager, to direct all manufacturing activities and related functions of its two Woodside, L.I., plants.

• **Beech Aircraft Corporation** has announced the Beechcraft Badger, a four-place twin-engined executive airplane with a cruising speed of about 200 m.p.h. Its two 180-hp. Lycoming engines took the new craft on its initial flight August 6. It is hoped that deliveries may be possible early in 1957.

• **Bendix Aviation Corporation . . .** Haydn R. Jones has been appointed Comptroller of the Eclipse-Pioneer Division, succeeding W. G. Majeske, retiring after 27 years' service. . . . Three new appointments have been made in the Aircraft Products Section of Bendix Products Division. Wilson A. Gebhardt has been named Section Manager of Aircraft Engine Equipment Products. William J. Kunz, Jr., and Rudolph Bodemuller will be Assistant Engineering Managers.

• **Boeing Airplane Company . . .** The first production model of the KC-135, new jet tanker, rolled from the plant on July 18 as President William M. Allen congratulated employees for their part in the "on schedule" delivery. . . . A small, special-purpose electronic analog computer has been developed by Boeing engineers to plot data as obtained during testing of models in the transonic wind tunnel. Cost, including adaptation, $12,000. . . . L. C. McMahan has been named company Senior Dayton Representative.

• **Curtiss-Wright Corporation . . .** The Wright Aeronautical Division outlines features of the new EA Series of Curtiss-Wright Turbo Compound engines in a brochure which pictures and discusses performance figures claimed for the new product. The booklet reports that the range of a typical four-engined transport may be increased 17 per cent with the EA Series power plants.

• **Douglas Aircraft Company, Inc. . . .** First photographs of the Navy's newest supersonic jet fighter plane, the Douglas X-F5D Skylancer, show it to have an almost wafer-thin, modified delta wing which rakes back from a long, slim fuselage. The X-F5D, according to officials, is rated faster than any American jet in squadron service. Designed for catapult take-off from all types of carrier, it is a multipurpose airplane and can be utilized as a general day fighter, all-weather interceptor, or as a fixed-point interceptor. . . . Climaxing a decade of DC-6 and DC-7 airliner production, Douglas on August 6 delivered the 700th transport in the series. The Santa Monica Division reports a backlog of 294 of the giant, piston-powered transports. . . . The first DC-7C left Santa Monica August 7 for Sweden to join the Scandinavian Airlines System. . . . The El Segundo Division has delivered the first AD-7 model of the Skyraider series to the Navy a month ahead of schedule. More than 3,000 of the carrier-based attack bombers have been built since 1946.

• **The Dow Chemical Company** has announced an expansion of its finishing and cathodic protection technical services for users of magnesium. Four research personnel of the Dow Metallurgical Laboratory will be transferred to the company's Magnesium Technical Service & Development Group and will devote full time to the finishing projects of individual customers. Another research engineer will join the cathodic Protection Sales Group to assist customers in projects utilizing magnesium anodes.

• **Elastic Stop Nut Corporation of America** reports development of a new flanged hexagon self-locking nut designed with a large washer-type seat for fastening applications involving spring tension, such as compressor motor mountings.

• **Fairchild Camera and Instrument Corporation** has appointed Major Gen. Kenneth P. McNaughton, USAF (Ret.), recent Vice Commander of the Far East Air Force, as Director of West Coast Operations. He will make his headquarters at the Corporation's new West Coast plant in Los Angeles.

• **Fairchild Engine and Airplane Corporation** has published a 6-page, two-color illustrated booklet on *The Case for the DC-3 Replacement*. The booklet, describing the Fairchild F-27 twin-engined prop-jet transport, is available from William G. Key, Fairchild Engine & Airplane Corporation, Hagerstown 15, Md.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation . . .** The Laboratories' expansion will be carried out on both coasts to keep pace with electronic industry needs. New buildings are slated for California's San Fernando Valley and at the Nutley, N.J., site.

• **The Firestone Tire & Rubber Company** has announced development of a new reinforced plastic tray for potential use in conveying small production items. A weight of 7 lbs. is claimed for the new item.

• **Flight Refueling, Inc. . . .** The A.F. Operation Test Center has begun work on the Boeing KB-50 aerial tanker, capable of refueling three planes simultaneously with the probe and drogue method. A combination of F-100's and B-66's will be used in the evaluation tests.

• **General Dynamics Corporation . . .** An electronic display device to help solve air traffic control problems has been announced by the Stromberg-Carlson Division. It is a commercial version of the Charactron shaped-beam tube used for some time in the SAGE system of military aircraft surveillance. . . . Convair Division in San Diego—by constructing its own especially designed trailer—has slashed by 90 per cent the cost of moving the delta-wing F-102A from assembly line to airport. . . . The Division reports purchase of 25 more Model 440's by United States and foreign air lines. . . . B. F. Coggan, Division Manager, reports that employees will receive double the amount of cash awards for adopted cost reduction suggestions under a revised cost improvement program. . . . The Division has leased a temporary laboratory in San Diego to implement the new basic research program. Six of the 25 to 30 scientists ultimately to comprise the staff have been retained. Explorations are scheduled in gas dynamics, aerodynamics, theoretical and experimental physics, physical chemistry, mathematics, and metallurgy. . . . First photographs of the

AVCO makes 18,000 m.p.h. stand still

ctual shock wave photographed through viewing port Avco's Hypersonic Shock Tube.

To speed development of an advanced Air Force missile system

The Hypersonic Shock Tube, developed by Avco scientists and engineers, has provided an accurate "testing ground" in the search for metallic materials and aeronautical designs which will withstand the heat created by 18,000 m.p.h. speeds. The effect of such hypersonic speeds can now be observed and recorded on a stationary model in the laboratory.

Already, findings of tests carried out in the "shock tube" have proven to be valuable contributions to the technology of advanced missile systems.

New frontiers in research have thereby been opened, which will lead to many exciting new careers.

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WRITE: Dr. Lloyd P. Smith, President, Avco Research and Advanced Development Division, 20 S. Union St., Lawrence, Mass., **OR PHONE** Murdock 8-6011

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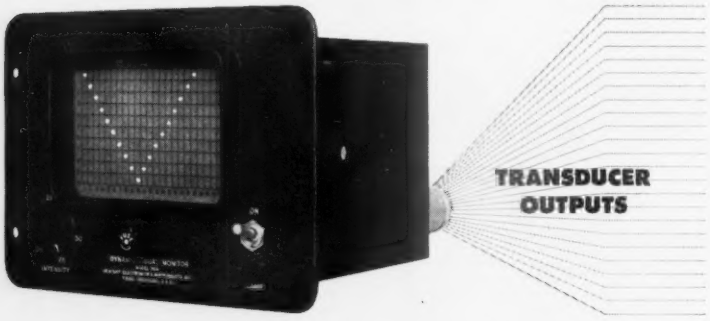
combine the scientific skills, and production facilities of 3 great divisions of Avco Manufacturing Corp.: Research and Advanced Development, Crosley, Lycoming—which currently produce power plants, electronics, airframe components, and precision parts.

Century MODEL 20 VISUAL MONITOR



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Does your data problem include any of the above? Or anything similar?

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Now you can observe and measure 24 separate data points, simultaneously. No Switching, no commutating, no time lag.

Wherever a graphic display of several quantities will facilitate measurement and control, the Model 20 should be considered.

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RADAR TEST SETS
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And other devices now in production for Army, Navy and Air Forces on prime and sub contracts.

MANCHESTER NEW HAMPSHIRE

NORTHEASTERN ENGINEERING INC.

Convair NB-36H, nuclear test airplane, have been released.

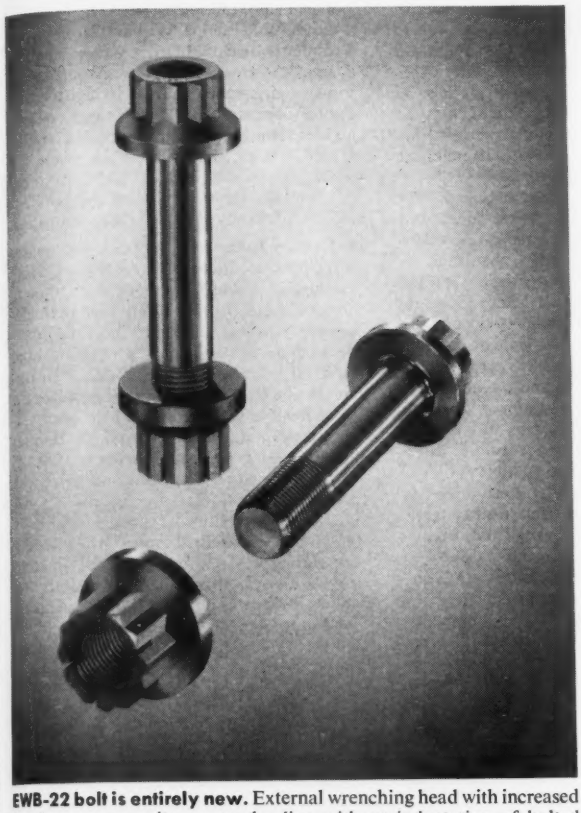
• **General Electric Company** has been revealed as one of the major firms participating in the USAF strategic ballistic missile development program; its work is concentrated on nose cone and guidance system development. The former problem has been described as one of the "most challenging today" by the Special Defense Projects Department. . . . A new Technical Military Planning Operation, with responsibility for preliminary planning of future complex weapons systems, is being organized in the Defense Electronics Division. Its manager will be Richard C. Raymond, formerly of The RAND Corporation. . . . An inch-square "honeycomb" developed by Harold R. Day, of the Research Laboratory, will store up nearly a million bits of information. . . . First successful demonstration of closed-circuit color television to observe firing of ballistic missiles was held recently at the Missile Test Center at Cape Canaveral, Fla. . . . An international group of engineers who aspire to United States citizenship is working on preliminary designs of aircraft power plants for the Company's Aircraft Gas Turbine Division at Cincinnati. Dr. Guenther Diedrich, designer of the pulse-jet engine used in V-1 buzz bombs of World War II, is one of those who has joined the project. . . . Higher material and labor costs are blamed for a price increase of $7\frac{1}{2}$ per cent on all fractional horsepower d.c. motors and generating equipment and two lines of fractional horsepower a.c. motors. . . . Three new bulletins are available. They are on the G-E hermetically sealed microminiature relay, the new 2PDT hermetically sealed subminiature relay, and control panel benefits offered by G-E.

• **General Precision Laboratory Incorporated** announces a new Specification Sheet on the GPL Ruggedized Television Camera, Model PD-152, said to operate successfully in extreme noise, shock, temperature, and vibration environments.

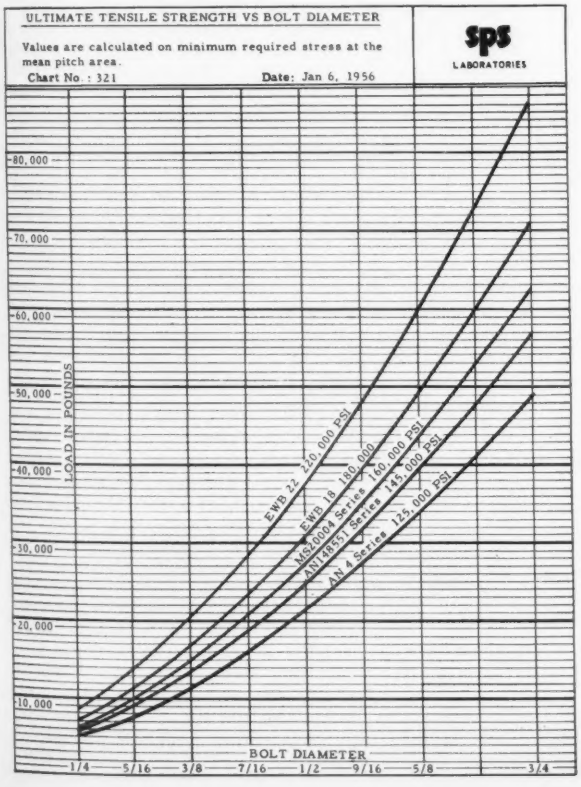
• **The B. F. Goodrich Company** has combined into a single operating division the manufacturing and selling functions of its aeronautical departments. The new unit will be known as B. F. Goodrich Aviation Products, a division of The B. F. Goodrich Company. P. W. Perdriau and E. H. Fitch have been named General Manager and General Manager—Sales, respectively. . . . William R. Tonge has been named Technical Manager, De-Icers and Aeronautical Accessories, as successor to Charles S. Stebbins, who has been transferred to the B. G. Goodrich International Company.

• **The Goodyear Tire and Rubber Company, Inc.,** reports that first executive-type aircraft equipped with tubeless tires are rolling off the Beech Aircraft Corporation line in Wichita, Kan. . . . The firm's new Tri-Metallic disc brake is said to contain some 200 parts less than conventional ones of comparable size and capacity.

• **Harvey Aluminum Division of Harvey Machine Co., Inc.,** announces finalization of arrangements for its 54,000-ton aluminum reduction plant at The Dalles, Oregon. The plant is scheduled for completion late in 1957.



EWB-22 bolt is entirely new. External wrenching head with increased bearing area permits greater loading without indentation of bolted surface. New Hi R thread form, generous fillet under head, smooth overall surface increase tensile and fatigue strength. The EWN-22 locknut was designed with characteristics specially suited to the bolt.



Build stronger, safer, lighter airframes with new SPS Hi Psi aircraft bolts

Conventional bolts were not strong enough to fasten jet-age aircraft now on drawing boards. So Standard Pressed Steel Co. discarded obsolete fastener configurations, materials and production techniques and designed a new high-strength bolt—the Hi Psi EWB-22—which is the strongest bolt made to this time.

Compared with conventional 160,000 psi bolts like the MS 20004 Series, the SPS EWB-22 has 38% greater tensile strength and, at 8 million stress cycles, up to 90% greater fatigue strength. These qualities make it feasible, in most cases, to replace a standard MS 20004 Series bolt with an EWB-22 *of the next smaller diameter*. The benefits from use of the EWB-22—in increased structural strength and security and in reduced weight—are obvious.

Concurrently with the development of the EWB-22, SPS produced the Hi Psi EWN-22 locknut to complement the bolt. It is a high tensile strength self-locking nut with a 12-point external wrenching surface. It makes possible the high wrenching torque needed to preload the EWB-22 to the greatest advantage.

Along with Hi Psi EWB-22 bolts and EWN-22 locknuts come other new additions to the complete SPS line of threaded aircraft fasteners—PLI-22 preload indicating washers, simple mechanical devices for accurately preloading the new high strength bolts. For detailed information about these products—or about your special aircraft threaded fastener problem—write us today. Aircraft Products Division, STANDARD PRESSED STEEL CO., Jenkintown 58, Pa.

AIRCRAFT PRODUCTS DIVISION

STANDARD PRESSED STEEL CO.

SPS

JENKINTOWN PENNSYLVANIA

EWB-22 is much stronger than conventional aircraft bolts. These curves, with ultimate tensile strength in pounds plotted against bolt diameter, show that it is feasible to replace an MS 20004 bolt with an EWB-22 one size smaller. The EWB-22 is stronger in shear and in fatigue as well.

• **Hydro-Aire, Inc. . . .** Five high-production military aircraft are using from one to twelve Hydro-Aire pumps per ship, according to President H. H. Rhoads. The Company also has developed a turbine-driven pump and a "double-end" booster pump for special applications.

• **The International Nickel Company, Inc.,** reports that 117 tons of cast nickel steel went into The Mountaineer, which, standing 16 stories high, is classified as the world's largest power shovel. The Mountaineer scoops up overburden in 90-ton chunks, and its bucket holds enough to fill two coal hopper cars.

• **Walter Kidde & Company, Inc.,** has elected to its Board of Directors William Collins, President, Walter Kidde Constructors, Inc.

• **Kollsman Instrument Corporation . . .** A new altimeter, said to be 400 per cent more accurate below 50,000 ft. and 100 per cent more accurate above that altitude, has been made public by ARDC. The instrument was developed by WADC in conjunction with Kollsman.

• **Lear, Incorporated . . .** Norman Warren, Director of Advertising and Public Relations, was elected a Vice-President by the Board of Directors in Grand Rapids, Mich., on July 13. In addition, Joseph M. Walsh, Assistant Division General Manager of the Grand Rapids Division, was elected Assistant Secretary. Forrest D. Beamer, previously Assistant Secretary, was elected Assistant Secretary and Assistant Treasurer. Re-elected were: Chairman of the Board, William P. Lear; President, Richard M. Mock; Executive Vice-President in Charge of Manufacturing, Andrew F. Haiduck; Vice-President and Treasurer, Chester D. Seftenberg; Vice-Presidents, Harold C. Andrus, Roy J. Benecchi, C. J. Breitwieser, A. G. Handschumacher, and Paul Moore; Secretary, Philip E. Golde; Comptroller, Albus Durham; Assistant Secretaries, Vernon B. Benfer and Albert C. Keske; Assistant Treasurer, Albert A. Rorison. . . . The Company, which recently announced a $3.6 million plant expansion program affecting three localities, has entered into a 10-year exclusive license agreement to manufacture and sell in the United States the turbine-engine control equipment developed by Ultra Electric, Ltd., of London. . . . The Aircraft Engineering Division has announced CAA approval of the adaptation to Lodestars of the Learstar mechanical rudder spring tab system. . . . The same division announced that the first Learstar Mark II Conversion of an executive Lodestar has received a Supplemental Type Certificate and has been delivered to Plymouth Oil Co., of Sinton, Tex. . . . The Lear-Romec Division announces an aircraft fuel pump designed to supply smoke fuel for a guided-missile tracking system. Further information may be obtained from the Division at Elyria, Ohio.

• **Lockheed Aircraft Corporation . . .** Demand for Electra and Super Constellation air liners in the first half of 1956 puts the Corporation's transport backlog at a record $465 million, more than double the mid-1955 figure, the company reports. . . . Plans are to expand manufacturing facilities at the Bakersfield, Calif., subassembly plant. . . . The California Division reports that the first Super Star Constellation, Model 1649A, featuring a new wing of 27 ft. greater span than earlier models, is taking shape in Burbank. It will carry 33 passengers in maximum luxury siesta arrangement or up to 80 tourist passengers at 350 m.p.h. cruise. Range is listed at 6,400 miles. Four turbocompounds will deliver a total of 13,600 hp. . . . Lockheed employees last year contributed $427,000 to charitable projects through the Buck-of-the-Month Club—a 15 per cent increase over 1954. . . . The Corporation reports its prop-jet C-130 Hercules has successfully dropped the heaviest single load—27,000 lbs. of iron weights—ever extracted by parachute from an airplane for aerial delivery. . . . A "parasite" radome, an ellipsoid measuring 30 ft. across and looking much like the popular conception of a flying saucer, has been fitted to a Navy WV-2 Super Connie to test advanced ideas in flying radar stations. After runway tests, flight effects of the fitting will be investigated. Later, the craft's electronics will be tested. . . . Transfer of Lockheed's nuclear-powered aircraft preliminary design study project, comprising some 150 engineers, from California to the company's Georiga Division at Marietta, Ga., is vitually complete, it is reported. . . . Lloyd E. Frisbee, formerly Flight Test Division Engineer, has been named Chief Research Development Engineer for the Georgia Division. . . . The C-130 Hercules, being produced "in quantity" at the Marietta plant, is listed as the fastest USAF transport in production. Top speed is put at over 370 m.p.h. The company says that on combat missions, with 25,800 lbs. of cargo and more than 5,000 gal. of fuel, the Hercules can cross the continent, or an ocean, nonstop at 330 m.p.h. cruise. A take-off and climb to 2,500 ft. in 60 sec. is reported. . . . A new hypersonic missile, product of the Missile Systems Division and Western Development Division, ARDC, has been disclosed, although its designation is classified. The Division also has designed and built a supersonic test vehicle designated the X-7, being used as a test bed to get test and design information and to develop successful ram-jets for operational use. The X-7 is being launched from a B-29.

• **McDonnell Aircraft Corporation** reports that the ARDC has announced that the McDonnell XV-1, the world's first successful convertiplane, unofficially exceeded the speed record for helicopters when it reached 200 m.p.h. The speed was reached just before successful completion of a flight evaluation program, conducted by the staff of ARDC's Flight Test Center from Edwards AFB, Calif. Captain Wayne W. Eggert, ARDC test pilot, made 39 flights in which five conversions were accomplished from helicopter rotor take-off, to airplane forward flight, and back to rotor for landing. A second XV-1 has been built and is flying.

• **Minneapolis-Honeywell Regulator Company** reports it will erect a $4 million aeronautical plant near St. Petersburg, Fla., to develop and produce inertial guidance systems. Some 1,500 engineers and skilled production people will be employed when full-scale production is reached, probably by mid-1957, Paul B. Wishart, Honeywell's President, disclosed. . . . A new bombing system known as LABS (low altitude bombing system), which enables jet fighters and fighter-bombers to carry and deliver atomic bombs, is being supplied to the USAF. With the system, the plane approaches a target at tree-top level, "tosses" the bomb, and then escapes blast effects by means of an acrobatic maneuver.

• **Norden-Ketay Corporation** announces three new products. A new transportable automatic trifilm processor for 16-mm., 35-mm., and 75-mm. film has been designed to allow simplified loading procedure, fine control over processing, and rapid drying. . . . Type 232 MK7 Instrumentation Camera has been designed as the most flexible camera in the field of instrumentation and air photography. Its uses include radar and oscilloscope recording, instrument panel recording, aerial survey positioning, and plotting records. . . . A new Transistor Curve Tracer, Model BCT 300, is said to be ideal for use when designing transitor circuits; comparing, matching, and selecting transitors; detecting anomalies; studying effects of temperature age, normal usage, overloading; and detecting failures and causes. Further information may be obtained from the corporation at 99 Park Avenue, New York.

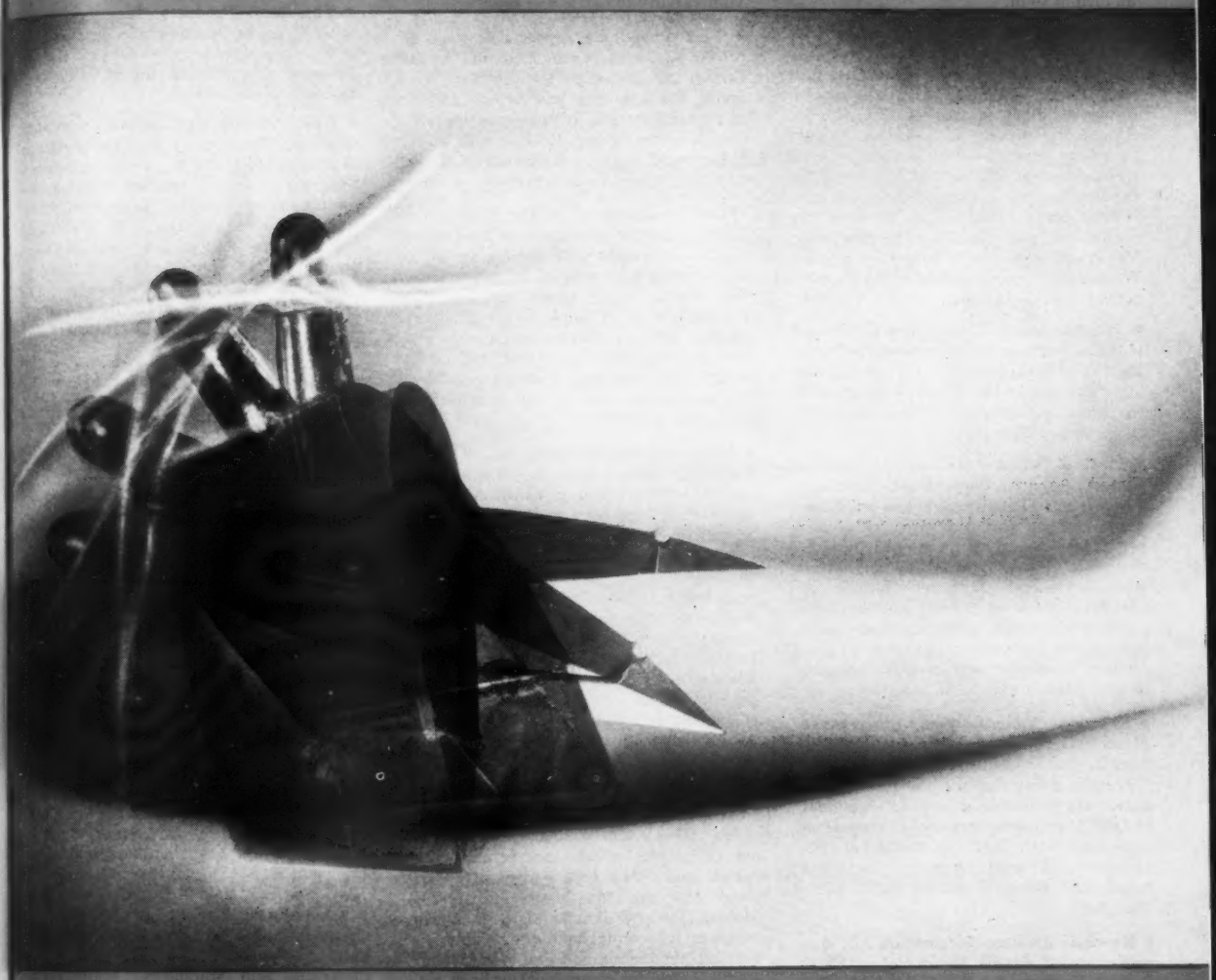
• **North American Aviation, Inc. . . .** The new F-100F Super Saber, a two-place version of the jet now in operational units, has been flown for the first time by Alvin S. White, engineering test pilot for the company. The plane, reported the world's fastest two-man airplane, is in production for the USAF. The F-100F was designed to be flown by one man on fighter and bombing missions. It also can carry an observer or student in the rear cockpit. Powered by a Pratt & Whitney J-57 axial flow turbojet engine with afterburner, the F-100F has a thrust rating in the 10,000-lb. class. Its maximum service ceiling is over 50,000 ft., and it has a range of more than 1,000 miles. . . . Rocketdyne Division reports confirmation by the USAF that it is developing high thrust rocket propulsion systems for the Air Force ballistic missiles program.

• **Northrop Aircraft Inc. . . .** The Board of Directors has elected Irving Roth and J. Grant Macdonnell to positions as officers. Mr. Roth, previously Staff Assistant to the President, was elected Assistant to the President. Mr. Macdonnell, formerly Assistant to the President, was elected Assistant Treasurer. . . . Company scientists are conducting studies to determine the limits of man's mental and physical abilities to command supersonic aircraft, Edgar Schmued, Vice-President—Engineering, has announced. Advanced studies will be undertaken by Psychologist Gerald F. Rabideau and Physiologist J. Gordon Wells. . . . Three electromechanical engineers, Bob Johnson, Doyle Henderson and Tom Morris, have developed a new time-saving cast-aluminum electronic chassis assembly kit said to be as simple as a child's building set. Two types of modular castings are used. One is cast with diagonal openwork ribs where air condition for components is necessary; the other is cast solid to permit shielding against inter-

Wings of old take on a new turn to bring true VTOL flight closer. Vertol research now takes on one of the most advanced assignments of the decade—high speed aircraft with vertical takeoff and landing capability.

Project: Vertol is now developing aircraft types which will fly as fast, as high, as far, as today's transports yet are able to take off and land at 0 mph forward speed.

Qualifications: Vertol's long-established leadership in the helicopter industry, Vertol's impressive research and development record in all aspects of vertical flight.



Progress: Vertol is currently developing a flying test bed for the Army under contract with the Office of Naval Research. In this aircraft—a small-scale variant of the larger, more powerful production types to come—a gas turbine drives rotor propellers housed in the wings of the aircraft. To takeoff and land vertically, both wings and rotor propellers pivot straight up; the rotor propellers furnish the necessary lift. At altitude, the wings tilt over into "normal" horizontal position, as the aircraft gathers flying speed; cruise is conventional and fast.

To give tomorrow's planes the universal landing and takeoff characteristics of today's helicopters is the essence of the Vertol "Skyways without Runways" concept.

VERTOL Aircraft Corporation

MORTON, PENNSYLVANIA

Engineers, join Vertol's advanced engineering team!

ference. . . . Scientists at the Pasadena Optical Laboratory are using the term "light fringe" to gage precision standards and ensure reliability of the USAF-Northrop Snark SM-62 intercontinental missile. A light fringe equals 0.000011 (11 millionths) of an inch, and many of the astronomical instruments manufactured by the company are held within a tolerance of one tenth of a light fringe—or 1.1 millionths of an inch in 10 in.

• **Pan American World Airways, Inc.** . . . Installation of radio navigational aids adjacent to El Coco International Airport at San Jose, Costa Rica, is providing improved Clipper service to the Central American capital. . . . Vibration damage to main bearings during long-distance truck shipment of Wright 3350 EA and DA engines has been eliminated by use of a bungee cord. The bungee preloads the engine after mounting on a shipping dolly. The system has been developed by Stanley W. Strama, superintendent of PAA's component overhaul shops.

• **Piasecki Aircraft Corporation** . . . Donald C. Lillis, partner in the investment banking firm of Bear, Stearns & Co., New York, and Chairman of the Board of Directors of the National Can Co., has been elected to the Board of Directors.

• **Pratt & Whitney Aircraft, Division of United Aircraft Corporation,** estimates more than 3,000 new employees will be required before year-end, when 40,000 in personnel—exceeding by several hundred the peak of World War II—may be at work. General Manager Wright A. Parkins reports outstanding success of the P&W J-57 engine—powering many first-line fighters and bombers in quantity production—as the prime reason for thousands of new jobs during the last year.

• **Reaction Motors, Inc.,** has elected Former Deputy Defense Secretary William C. Foster Chairman of the Board of Directors, filling the position for the first time. He is an Executive Vice-President of Olin Mathieson Chemical Corporation, associated with RMI in the supersonic aircraft and guided-missile propulsion fields, and formerly served RMI as a Director.

• **Republic Aviation Corporation** . . . Appointment of Robert W. Boesel as Chief Project Engineer for the Guided Missiles Division has been announced. . . . A new engineering and administration facility for the Guided Missiles Division is located at 233 Jericho Turnpike, Mineola, N.Y. . . . Robert W. Wichser, Chief Research Engineer, has been named to a special panel organized to keep the U.S. Department of Defense informed on developments in the use of titanium. The panel, of nine men, was appointed recently by the National Academy of Sciences at the request of the Assistant Secretary of Defense in charge of Research and Development. . . . The supersonic, nuclear-weapons-carrying F-105 has been officially christened the Thunderchief. The plane, reported performing "exceptionally" in its tests at Edwards AFB, is beginning to enter production at the Farmingdale plant. . . . Albert Hapke has been appointed Assistant Director of European Service. . . . The company reports development of a simplified tandem hydraulic-powered actuator system for aircraft primary flight controls which provides greater safety for pilot and plane and yet costs and weighs less than earlier systems. The development provides two completely independent mechanisms, each with its own tank and associated plumbing strategically dispersed through a military aircraft for reduced vulnerability to battle damage.

• **Paul Rosenberg Associates** has received an access permit from the Atomic Energy Commission for nuclear work under the following categories: Physics and Mathematics; Instrumentation; Radiation Effects on Reactor Materials; Health and Safety; Radioactive Waste; Reactors, Research and Testing.

Shell Oil Company . . . The Port of New York Authority announces it has authorized an agreement with Shell to install an underground fuel system and sell aviation fuel for a 5-year period at the Port Authority's West 30th Street Heliport. Sixteen 550-gal. underground tanks, with two grades of helicopter fuel, will be installed, together with hydrant outlets at the two landing and take-off pads and the helicopter parking.

• **Simmonds Aerocessories, Inc.,** of Tarrytown, N.Y., announces a new 8-page booklet (AD-404), which is available on request, describing the Liquid Level Sensing System recently developed. The system is capable of operating a lamp to indicate that gasoline, oil, or other liquid is above or below a certain level. It can also be used to provide control to start and stop pumps or operate valves to transfer liquid from one tank to another. The system is adaptable to a great variety of liquids and liquefied gases either relatively inert or chemically active and over a wide range of liquid temperatures and pressures.

• **Solar Aircraft Company** . . . Walker G. Dollmeyer has been named to the newly created position of Vice-President—Operations. He will direct Solar's manufacturing operations which include the company's main San Diego plant, the San Diego Airframe Parts plant, and the Des Moines, Iowa, Wakonda plant. . . . The company is becoming increasingly active in missile components, air-frame assemblies of stainless steel for commercial air lines, new types of jet-engine components, and gas-turbine engines produced for several new applications.

• **Stroukoff Aircraft Corporation** . . . An early fall rollout of the YC-134, USAF assault transport and support aircraft, has been tentatively scheduled. It is reported that the YC-134, the first support aircraft to have both boundary-layer control and the Pantobase all-surface landing gear, will offer exceptional take-off and landings, in extremely short distances, at better than one half the time and distance required for an aircraft of its 65,000-lb. weight class. Power will be two Wright R-3350 turbo-compound engines delivering 3,500 hp. for take-off.

• **Summers Gyroscope** . . . John M. Wright has been promoted to Director of Customer Relations.

• **Thiokol Chemical Corporation** has acquired a 12,000-acre plant site near the north shore of Utah's Great Salt Lake. The property will become the company's western facility for research, development, and manufacture of solid propellant rocket motors for guided missiles. Initial operations are expected to start about January 1, 1957, and more extensive operations will begin by July.

• **Thompson Products, Inc.,** has joined with American Bosch Arma Corporation in a licensing agreement to develop further, promote, and manufacture an automobile fuel injection system.

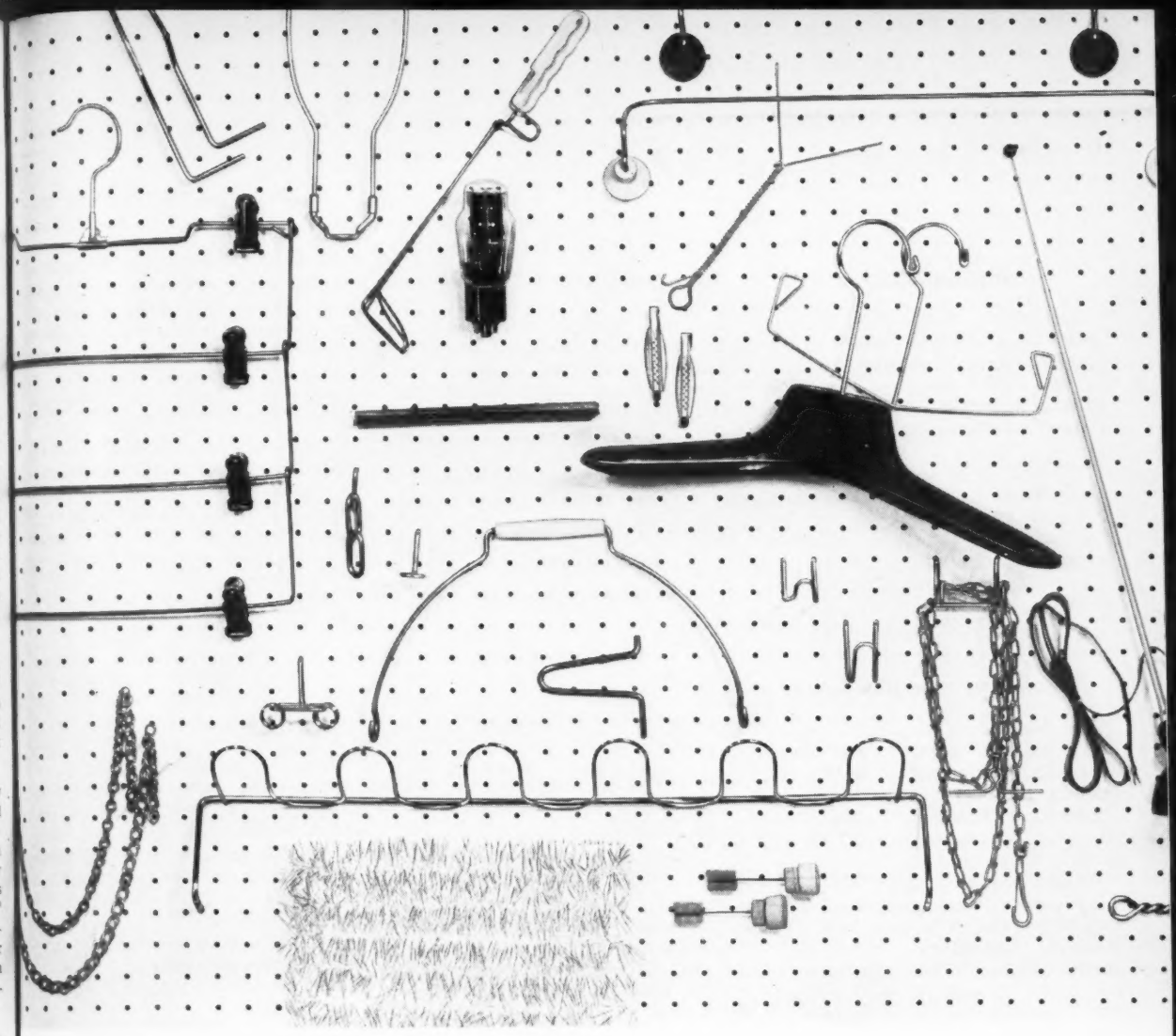
• **Union Carbide and Carbon Corporation** announces availability of a new booklet on Hastelloy Alloy R-235—a wrought, nickel-base, aluminum and titanium-bearing, precipitation-hardening alloy with outstanding properties through 1,750°F. Good oxidation resistance, low strategic alloy content, and a remarkable resistance to overaging in service are claimed. The booklet may be obtained from Haynes Stellite Company, 30-20 Thomson Avenue, Long Island City 1, N.Y.

• **United Air Lines, Inc.** . . . Henry T. Harrison has been appointed Director of Meteorology while T. M. Plunkett assumes the newly created post of Weather Control Manager. Their headquarters will be at the Operating Base, Denver.

• **Vickers Incorporated** announces a new line of in-line relief valves for air-borne oil hydraulic applications which combine accurate control and fast response with "flat" performance characteristics. They are designed for use in 3,000-psi systems having operating temperatures up to 650° F. . . . The Sixth Transport Aircraft Hydraulic Conference has been scheduled for November 13 and 14 at the Park Shelton Hotel, Detroit. Attendance is by invitation only.

• **Weber Aircraft Corporation** . . . Appointment of Arnold Johnson, 33 years with Weber, as Senior Vice-President and of Fred Godfrey as Vice-President—Manufacturing, has been announced by President E. K. Meredith. . . . Thomas J. May has been named Supervisor of the Engineering Analysis Group and will be in charge of analysis and testing in aerodynamics, structures, weights, processes, materials, and standards; spare parts analysis; and engineering services. . . . Darrell G. Smittle has joined the company as staff Engineering Supervisor in the Commercial Seating Division . . . . A case history file describing the buffet, food handling equipment, and passenger seats in the USAF MAT Service long-range Super Constellations is available from the company at 2820 Ontario Street, Burbank, Calif. Also available is a folder in which to file this and subsequent case histories relating to Weber interior equipment for military and commercial aircraft.

• **Westinghouse Electric Corporation** has installed an environmental testing chamber—used to evaluate the effect of various weather conditions on air-borne electronic systems—at headquarters of the Air Arm Division, Baltimore. One man operates the chamber. Temperatures can be regulated from −100°F. to +500°F.



How these products were improved and costs lowered . . . with **NICKELPLY*, BRASSPLY*** and **COPPERPLY*** wire!

• National-Standard Nickelply, Brassply and Copperply is electro-jacketed steel wire—a new development offering important advantages to manufacturers and users of wire forms and components. Specifically . . . . .

The jacket metal, precisely concentric and to the required thickness, *is inseparably bonded to the steel wire.* The materials can be severely formed, twisted, swaged, welded, roll threaded or redrawn without fracturing the jacket metal or otherwise exposing the base metal. Thus these new materials can often replace solid nickel, brass or copper wire, or can eliminate the costly post-plating of steel wire forms . . . and with unmatched assurance of coating coverage! Advantages in strength, durability and economy are obvious.

Nickelply, Brassply and Copperply are now available commercially in diameters up to .340". Pertinent data on coating weights, strengths, finishes, base materials, corrosion resistance, etc., are given in Bulletin K-10. Why not send for it now and explore these new possibilities?

*Trade Mark National-Standard Company

NATIONAL-STANDARD COMPANY • NILES, MICHIGAN
Tire Wire, Stainless, Fabricated Braids and Tape

ATHENIA STEEL DIVISION • CLIFTON, N. J.
Flat, High Carbon, Cold Rolled Spring Steel

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Special Machinery for Metal Decorating

WORCESTER WIRE WORKS DIVISION • WORCESTER, MASS.
Round and Shaped Steel Wire, Small Sizes

IAS SECTIONS

Baltimore Section

Richard W. Sanford, MIAS, has been elected Chairman and Lt. Col. Leon S. Jablecki, USAF, Vice-Chairman for 1956–1957. Other new officers are R. G. Clanton, Secretary, and Monroe Duke, Treasurer.

H. C. Johnson, C. A. Naegeli, and R. L. Zouck were elected to the Advisory Board for 2 years. Elected to 1-year terms were F. H. Clauser, Lt. Col. H. C. Leubner, E. G. Uhl, and Herman Pusin.

Seymour W. Herwald is Area Councilor.

R. C. ROBLEY, *Secretary*

Chicago Section

The Nominating Committee's slate of candidates was approved unanimously at the May meeting, and the new Chairman for 1956–1957, Leland W. Sims, Director of Engineering Training at The Aeronautical University, Inc., brought the meeting to a close.

Elected Vice-Chairman for 1956–1957 was Harry W. Wiant, outgoing Secretary, who is Project Engineer for Cook Research Laboratory. Robert F. Hunter, Assistant Chief Engineer for the Shafer Bearing Division, Chain Belt Company, was elected Secretary. New Treasurer is W. H. Tarbox, a Flight Engineer for Trans World Airlines.

Named to the Advisory Board were K. L. Burroughs, President, The Aeronautical University, Inc.; R. O. Brittan, Project Engineer, Argonne National Laboratory; Harold V. Hawkins, Assistant Director, Cook Research Laboratory; T. C. Linnert, Head of Engineering, Air Line Pilots Association; William J. Pocock, a partner in the firm of Booz, Allen & Hamilton; R. A. Schram, Works Standards Manager, Shafer Bearing Division, Chain Belt Company; Lt. Col. D. J. Smith, Commander of the 126th Fighter Bomber Group of the Air National Guard; and A. F. Stott, Dean of Engineering at The Aeronautical University, Inc.

Howard H. Warzyn, of the National Safety Council, was the representative to the Nominating Committee for Area Councilors.

Earlier in the evening, about 125 members and guests gathered at the Glenview Naval Air Station where the Navy presented an interesting exhibit of Cougars, jet trainers, and helicopters. Dinner at the Officers Club followed.

▶ At the April meeting, about 110 members and guests assembled at the Western Society of Engineers and, following dinner, heard Lt. Col. John Paul Stapp tell of his experiences during sled runs at Holloman Air Force Base. After his talk, questions from the floor indicated a consuming interest in crash survival and provided a lively, informative conclusion to the evening.

HARRY WIANT, *Secretary*

Detroit Section

Ludwig A. Majneri, AFIAS, has been elected Chairman and Charles Vogel Vice-Chairman for 1956–1957. Other new officers are Fred J. Wilhoff, re-elected Secretary, and Richard Chute, Treasurer.

FRED J. WILHOFF, *Secretary*

Earth Satellite

Los Angeles Section

Some 45 to 50 nations, including the U.S.S.R. and Red China, will participate....$12 million will be spent by the United States, though more will be needed....The continued collaboration of scientists and institutions throughout the country will be required.

These and other facts about the International Geophysical Year (IGY)—principally in relation to United States participation—were outlined by Joseph Kaplan at the May dinner meeting. Dr. Kaplan is Chairman, U.S. National Committee for the IGY, and Professor of Physics, University of California at Los Angeles.

Introduced by H. J. Stewart, Professor of Aeronautics at California Institute of Technology, Dr. Kaplan told his audience that the time selected for the major international effort will make possible the planning of especially coordinated and intensified world efforts on such occasions as expected intervals of unusual magnetic, ionospheric, or auroral activity, on days of solar eclipses and during meteor showers.

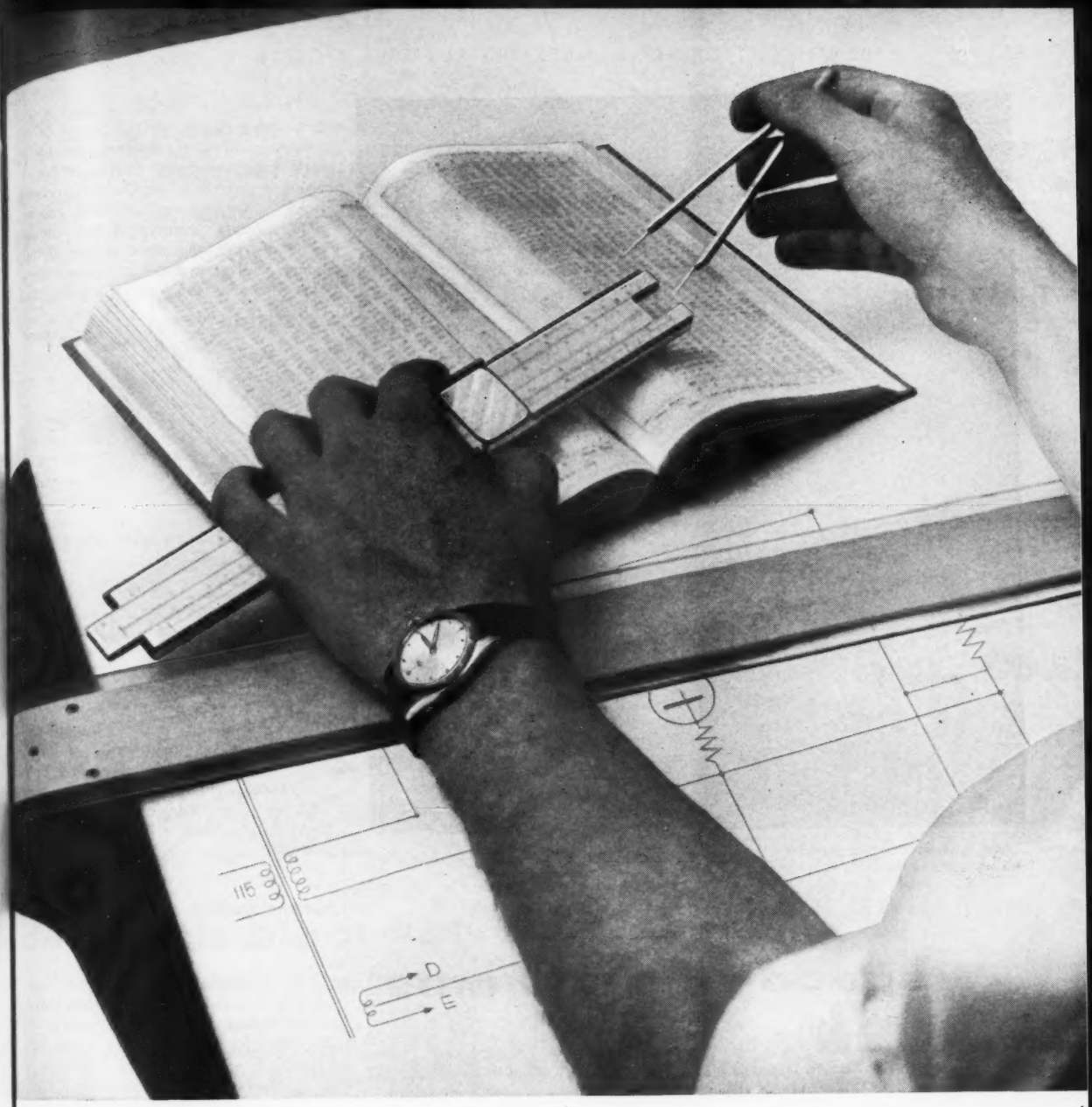
The Section was told that one of the reasons why such great importance is placed on the earth satellite is that—in contrast to high-altitude rockets—it is expected to stay aloft for a period of time which will permit gathering of much more information than is possible with vehicles restricted by short flying times.

▶ During the April meeting, members heard D. P. Huddie, Chief Development Engineer of Rolls-Royce Limited, in a presentation of his paper, "The Development of Rolls-Royce Propeller Turbine Engines." Mr. Huddie, pointing to no increase in the outside diameter of the Dart engine (powering the Viscount) since it was originated, said that performance improvement from 840 cruise hp. in 1953 to 1,840 cruise hp. in 1961 was obtained by increased mass flow, increased turbine inlet temperature, increased turbine efficiency, increased compression ratio, and decreased combustion pressure loss.

Mr. Huddie said the economic case for the propeller turbine-engined aircraft for short to medium ranges at 450 m.p.h. rests solely on the inherently greater flexibility of this power plant. The fuel penalty for cruising at other than optimum altitude is less than with the jet engines, as is also the fuel penalty for prolonged stacking.

One of the highlights of the June field trip of the Seattle Section was the inspection of the Nike missile at the Midway Nike site. An explanation of the missile's various features came to attentive onlookers via a loudspeaker. A lecturer may be seen pointing to the weapon midsection. Almost 400 members and guests participated in the field trip.

U.S. Army Photo



What's most important in this picture?

Not the slide rule, though it's helpful. Nor the divider. Nor the logarithm table. It's the human hand, of course, because it is motivated by the long, strong arm of human intelligence. It belongs to the career engineer dedicated in his service to the Department of Defense.

His mind and his hand shorten the coupling between a need urgently expressed by the military and its translation by industry into reliable electronic equipment. His experience contributes invaluable help at a critical stage in developing great new things in aviation electronics.

In Aviation Electronics LMEED Products Include . . .

FIRE CONTROL RADAR • SEARCH RADAR • INDICATORS AND DISPLAY • COUNTERMEASURES • NAVIGATION
MISSILE CONTROL • AIRBORNE SONAR • COMMUNICATIONS • FUZES • AUTOMATIC TEST • DATA PROCESSING

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Progress Is Our Most Important Product

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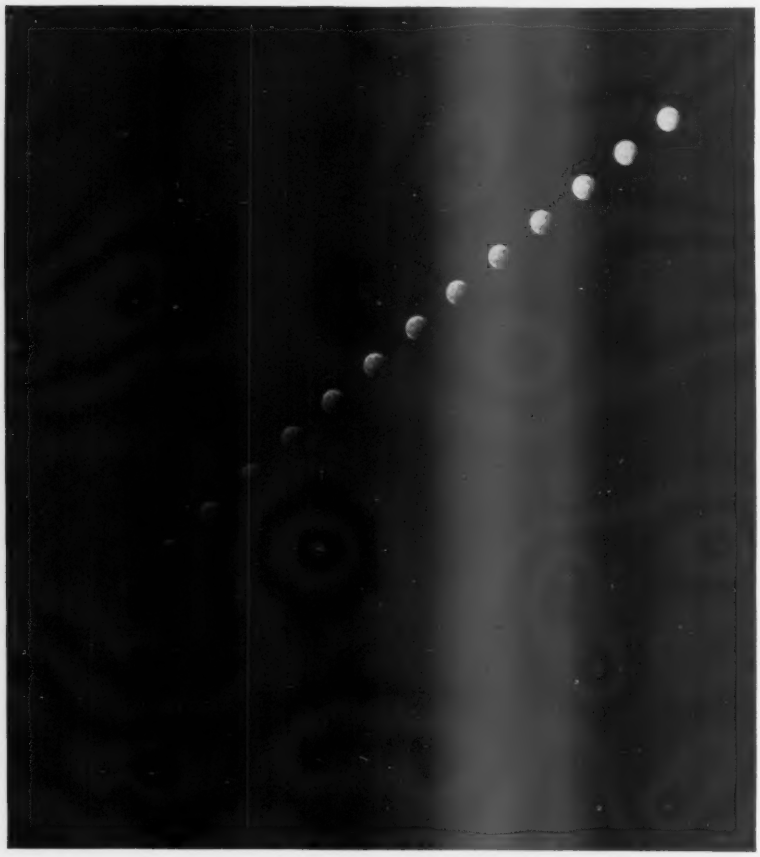

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Here you will find professional opportunities without limit—plus good living for you and your family in the healthful, colorful Colorado Rockies. For more information on both scores, we invite you to write Emmett E. Hearn, Employment Director, P.O. Box 179, Dept. A-10, Denver 1, Col.

MARTIN
DENVER DIVISION

The speaker, indicating the many test hours run and the amounts of money spent on the Dart to provide a civil engine without a military background, said that over the total operation so far the unscheduled engine removal rate averages 0.288 engine removals per thousand engine flying hours, and the average for all operators over the year 1955 was 0.182 for the Dart.

R. G. FULLER, *Secretary*

St. Louis Section

John F. Yardley has been elected Chairman and L. A. Smith Vice-Chairman for 1956–1957. Other new officers are W. J. Blatz, Corresponding Secretary; L. A. Perrin, Recording Secretary; and D. W. Allen, Treasurer.

Named to the Advisory Board were G. C. Covington, W. B. Bunker, and L. Harrison.

San Antonio Section

The following are new office holders for 1956–1957: Col. Claude W. Smith, USAF (M), Chairman; William C. Robinson, Vice-Chairman; Joseph W. Draper, Jr., Secretary; and Lt. Raymond J. Tolosko, USAF, Treasurer and Program Chairman.

Major Gen. Clements McMullen, USAF (Ret.) (AF), will serve the Section as Honorary Chairman.

National Defense

San Diego Section

The highlight of the year for this Section occurred in August, when Garrison Norton, Assistant Secretary of the Navy for Air, presented a talk on "The Navy's Role in National Defense" at a special dinner meeting. The session was well attended by members, executives from local aircraft companies, and leaders of Naval aviation activities in the San Diego area.

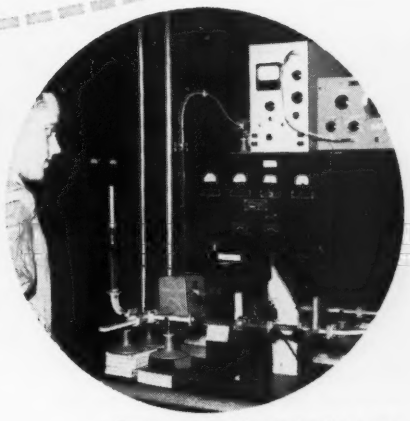
The meeting followed a special reception at the San Diego Speed Boat Club. Here, principal guests, corporate representatives, and Section officers with their wives had the opportunity for an informal get-together. Afterward, dinner was served at the Institute Building. Frank Fink, Vice-President and Chief Engineer, Ryan Aeronautical Company, served as toastmaster following an introduction by Section Chairman Earl R. Hinz.

Mr. Norton emphasized the important role which will be assigned the Navy in wartime and its function in deterring war, discussing additions to the fleet and various missile programs and covering developments in carrier and water-based categories.

The right people with the right facilities produce the right solutions

The new Sylvania Microwave Physics Laboratory, Mountain View, California.

Results of gaseous electronics investigation concerned with wide-band tunable microwave oscillations are examined at the Microwave Physics Laboratory. From left: Laboratory Manager, O. T. Fundingsland; Dr. R. M. Hill, senior project leader, gaseous electronics; Dr. P. H. Vartanian, senior project leader, ferrites; and Dr. A. L. Aden, assistant laboratory manager.



Frequency doubling in ferrites, a phenomenon newly discovered at Sylvania Mountain View laboratories, is studied by engineer A. L. Helgesson.

More problem-solving power...

Sylvania's new Microwave Physics Laboratory

NEW PROBLEM-SOLVING POWER has been added to Sylvania's growing capability for research and development in highly advanced military and industrial electronic systems.

With the establishment of the Microwave Physics Laboratory at Mountain View, Calif., Sylvania is expanding its work in new magnetic materials and ionized gaseous media for microwave electronic control devices and systems for radar, communications, and electronic countermeasures.

Fields of research at the laboratory include magnetic ferrites, gaseous electronics, radio wave propagation, electromagnetic resonance phenomena in ferrites and ionized gaseous media.

Besides the new Microwave Physics Laboratory, the Microwave Tube Laboratory and the Electronic Defense Laboratory are also located at Mountain View. Each is a vital part of Sylvania's Electronic Systems Division.

In addition to the Mountain View laboratories, the Electronic Systems Division has plant and laboratory facilities at Buffalo, New York, and extensive research facilities at Waltham, Massachusetts. All are staffed with top-ranking scientists and engineers, backed by Sylvania's extensive resources in the electronics field.

SYLVANIA IS LOOKING FOR ENTERPRISING ENGINEERS

Sylvania has many opportunities in a wide range of defense projects. If you are not now engaged in defense work, you are invited to contact Edward W. Doty, Manager of Personnel, Electronic Systems Division, Sylvania Electric Products Inc., 100 First Avenue, Waltham 54, Mass.

SYLVANIA

LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

See Sylvania at the Annual Symposium on Aeronautical Communications, Oct. 8, 9, 10, Hotel Utica, Utica, N. Y., Booth 9

Assistant Secretary of the Navy for Air Garrison Norton is shown speaking before the San Diego Section on "The Navy's Role in National Defense." Seated at *left* is Earl R. Hinz, Section Chairman. At *right* is Vice-Admiral Alfred Pride, Commander, Air Force Pacific Fleet.

He declared that nations seeking to dominate the world by force must find alternatives to all-out nuclear surprise attack and that this country must provide defense against these alternatives. He also indicated the responsibilities of the technical people and the IAS members in particular to help solve these problems by understanding the objectives and capabilities of the Navy.

Among special guests were Vice-Adm. Alfred Pride, Commander Air Force Pacific Fleet; Rear Adm. C. C. Hartman, Commandant 11th Naval District; Rear Adm. A. B. Vosseler, Commander Naval Air Bases, 11th and 12th Naval Districts; T. C. Ryan, President, Ryan Aeronautical Company; J. V. Naish, Executive Vice-President, and R. C. Sebold, Vice-President—Engineering, of Convair, A Division of General Dynamics Corporation; Alexander Black, Vice-President—Sales, and W. C. Heath, Projects Manager, Solar Aircraft Company; and Frank E. McCreery, Vice - President—Engineering, Rohr Aircraft Corporation.

▶ Paul P. Datner, Senior Engineer, Aerojet-General Corporation, presented a paper on "Thrust Reversers" at the meeting on July 19, discussing developments which have led up to the Aerojet thrust reverser. General principles of thrust reversal were pointed out, and many of the technical and hardware problems were discussed. A film on Aerojet-General work in the field supplemented the talk.

▶ "Project Smart" was the subject of the technical meeting on June 28 at the Institute Building. The paper was presented by Hugh B. Thompson, Project Engineer, Coleman Engineering Company, Los Angeles, who discussed the supersonic military air research track at Cedar City, Utah. The facility provides for observation of full-scale, high-speed ejection and bail-out characteristics without endangering the lives of airmen and without risking aircraft. The project is part of an overall U.S. Air Force "Human Engineering" program for greater safety in supersonic flight conditions.

Progress is reported by the Museum and Historical Committee on two projects—developing photomurals for permanent display in the foyer of the San Diego IAS Building and constructing an authentic replica of the 1883 John Montgomery glider.

R. A. FUHRMAN
Corresponding Secretary

STUDENT BRANCHES

Academy of Aeronautics

Robert Bradshaw, an engineer with Grumman Aircraft Engineering Corporation, addressed members at a special June meeting on "Manufacturing Processes." He presented an interesting insight into the duties of a manufacturing engineer.

Also in June, a combined IAS and SAE dance was attended by 400 students and guests. Funds were earmarked for a free dance for members of the graduation class.

MERTON S. BEEBE
Corresponding Secretary

Herman R. Oswell, *right*, 1956 graduate of Alabama Polytechnic Institute, wins recognition from B. G. Bromberg, Chief Engineer, Missile Engineering Division, McDonnell Aircraft Corporation, after receiving the IAS Student Branch Certificate of Award from his school. The award is given for the best scholastic record in aeronautical engineering during the junior and senior years. Mr. Oswell is an Associate Engineer (air frames) with McDonnell.

Alabama Polytechnic Institute

A discussion on "The Development of High-Speed Water Vehicles" by their Secretary was presented before members of this Branch at the July 24 meeting. The officer is a senior in Aeronautical Engineering.

Members also heard a report by Howard Watson, Acting Treasurer. A motion picture about the Bell X-1A closed the session. Thornton A. Walker was welcomed as a new member.

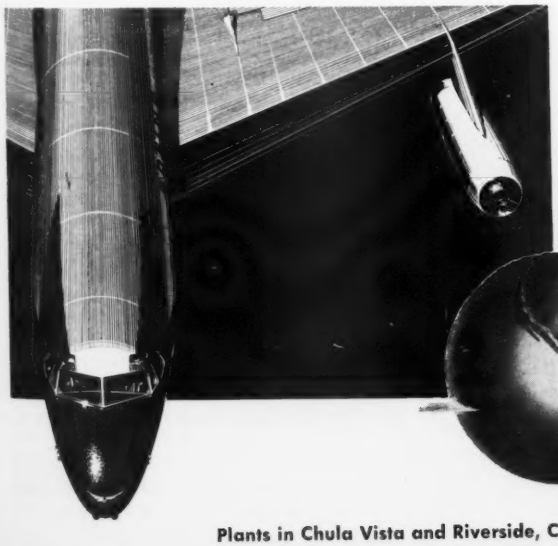
At the July 10 meeting, K. A. Gustafson, Project Engineer on the Chance Vought guided missile, Regulus I, made the principal address, describing his experiences with the air vehicle. Plans were discussed for a visit to Pensacola Naval Air Station and a tour of an aircraft carrier.

350-TON HUFFORD STRETCH FORMER — PART OF ROHR'S MULTI-MILLION DOLLAR TOOL KIT

This giant Rohr machine is one of the two largest of its kind in the world. It permits the forming of an increasing variety of large size stringers, stiffeners, skins and fillet fairings . . . it makes possible the forming of deep outsized contoured parts considerably beyond the capacity of standard stretch machines and conventional presses.

Today, with this and hundreds of other heavy manufacturing machines, Rohr produces over 30,000 different parts for aircraft of all types. This is, of course, in addition to Rohr's being recognized as the world's largest producer of ready-to-install power packages for airplanes.

For design and engineering know-how, for full production facilities look to Rohr to build more into the aircraft parts you need.



In addition to the Boeing KC-135 shown here, Rohr builds power packages for many other leading commercial and military planes which have made Rohr famous as the

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POW-R-PAX FOR AIRPLANES

ROHR AIRCRAFT CORPORATION

Excellent career openings now for engineers and skilled technicians

Plants in Chula Vista and Riverside, California; Winder, Georgia — soon to be in Auburn, Washington

John E. Evers, Frank M. Awbrey, Jr., Robert F. Rodgers, James L. Rice, Jr., and Tommy R. Watts were welcomed as new members.

JOHN A. BARNES
Recording Secretary

Indiana Technical College

Maurice Landford has been elected Chairman and Anton Zadel Vice-Chairman. Other new officers are Rex Pierson, Treasurer, and Norman Beeler, Secretary.

At the August 7 meeting, Chairman Landford described the Speakers Bureau at McDonnell Aircraft Corporation. A bowling team was formed, with Mr. Landford volunteering to act as captain.

WAYNE C. BOHANNON
Secretary

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Barish, David T., M.S. in Aero., Sr. Consultant, Barish Associates.

Gertz, Arthur P., M.E., Engrg. Dept. Head, Sperry Gyroscope Co. (Great Neck).

Hall, Nathan I., M.S. E.E., V-P, Dir., Weapon Systems Devel. Labs., Hughes Aircraft Co.

Moeckel, Wolfgang E., B.S., Asst. Chief, Supersonic Propulsion Div., Lewis Flight Propulsion Lab., NACA.

Runckel, Jack F., B.S., Group Leader, NACA (Langley Field).

Runyan, Harry L., M.S. in Ae.E., Aero. Research Scientist, NACA (Langley Field).

Transferred to Associate Fellow Grade

Bateman, Robert E., B.S. A.E., Sr. Group Leader, Aerodynamics P. D., Plant No. 2, Boeing Airplane Co. (Seattle).

Brough, James N., B.A., Officer Commanding, RCAF Tech. Service Detachment, A. V. Roe Canada, Ltd.

Mar, James W., Sc.D., Asst. Prof.—Aero. Engrg., Massachusetts Institute of Technology.

Olson, Walter T., Ph.D., Chief, Fuels & Combustion Research Div., Lewis Flight Propulsion Lab., NACA.

Elected to MEMBER Grade

Coontz, Leland I., Jr., B.S., Designer, Power Plant, Douglas Aircraft Co., Inc.

Davies, Richard L., B.S. in E.E., Field Engr., Pacific Scientific Co.

Eulberg, Alvin C., B.S.C.E., Structures Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Forbes, Gordon R., Sr. Flight Test Engr., Special Projects Div., Lockheed Aircraft Corp.

Frazee, Donald L., B.S., Lead Stress Engr., McDonnell Aircraft Corp. (St. Louis).

Isom, James, Jr., B.S.M.E., Aerodynamicist, Bell Aircraft Corp.

Miller, Justin O., B.S., Supvr., Aero. Engrg. Sect., Hughes Aircraft Co.

Navoy, Helen, B.S., Systems Analysis Engr., Chance Vought Aircraft, Inc.

Peduzzi, Anthony M., Design Engr., Aerojet-General Corp.

Rohde, Ernst M., Asst. Aviation Mgr., Shell Oil Co. (Los Angeles).

Rose, Anthony A., Design Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Sant Angelo, Michael A., M.S.E.E., Sr. Project Engr., Sperry Gyroscope Co.

Schmidt, Kenneth W., Prod. Design Engr., North American Aviation, Inc. (Los Angeles).

Sidenstick, James E., B.S.M.E., Design Engr., General Electric Co. (Evendale).

Suer, Herbert S., Sc.D., Sr. Struct. Research Engr., North American Aviation, Inc.

Tomlin, Keith H., B.Sc., Aerodynamics Engr., Prelim. Design Group, Special Projects Div., Lockheed Aircraft Corp.

Torre, Cosimo, Dr. Ing., Prof., Dept. Mech. Engrg., Syracuse Univ.

Volkert, Paul K., B.S. in M.E., Flight Analyst "A," Boeing Airplane Co. (Seattle).

Wakeford, Ronald C., Dir. of Research & Engrg., General Astronautics Corp.

Watson, Frederic R., B.S., Sr. Engr., Products Application Dept., Shell Oil Co. (San Francisco).

Werner, Julius M., Ph.D., Asst. Prof., Mech. Engrg. Dept., Syracuse Univ.

Williams, Thomas W., B.S.M.E., Pres., ROC Associates, Inc.

Wong, Henry H. Y., B.S. in Ae.E., Sr. Stressman, The de Havilland Aircraft Co., Ltd.

Transferred to MEMBER Grade

Abbott, Lawrence S., B.S. in Ae.E., Struct. Engr., Cessna Aircraft Corp.

Broere, Richard B., B.S., Sales Engr., Fluid System Components, Parker Aircraft Co.

Brougham, Harold E., B.S.M.E., Lead Struct. Design Engr., Chance Vought Aircraft, Inc.

Davidson, Valentine, M.S., Group Leader, Dynamic Testing, Canadair, Ltd.

Firman, Roy S., B. of M.E. (Aero.), Product Design Engr., Light Military Electronics Equipment Div., General Electric Co. (Utica).

Harris, Robert H., B. of Ae.E., Mgr., Aviation & Defense Industries Sales, General Electric Co. (Atlanta).

Krause, Lloyd N., M.S. in Ae.E., Aero Research Scientist, Instruments, NACA.

Leggee Richard E., B. of Ae.E., Proj. Engr., Flight Test Center, General Electric Co. (Schenectady).

Sterzik, Kurt E., B.S.E. (Aero.), Flight Test Engr., North American Aviation, Inc.

Whitehead, Belleville, Jr., B.S.M.E., Flight Test Engr., Boeing Airplane Co.

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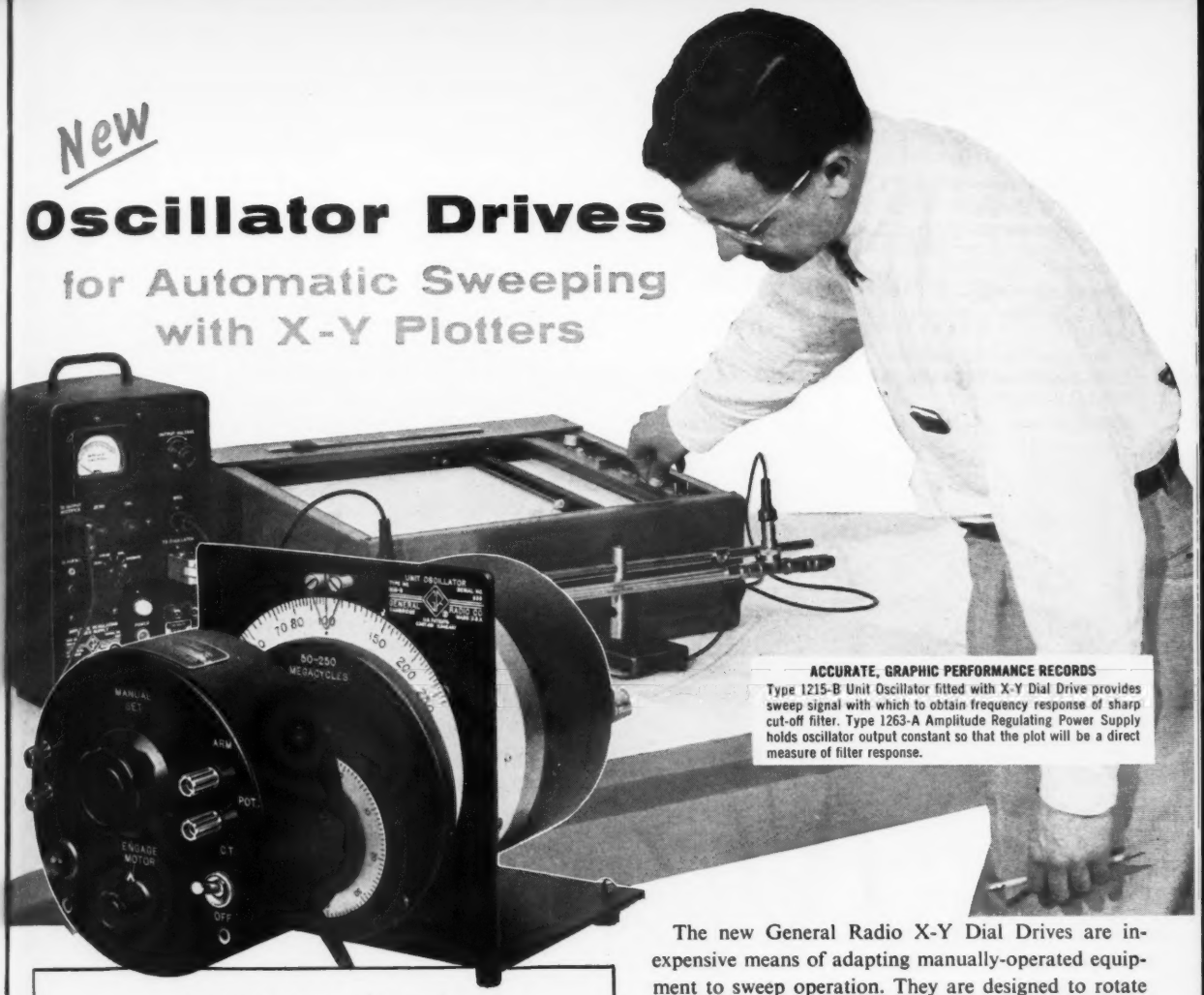

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Acoustics, Sound, & Noise

On the Acoustic Radiation from Boundary Layers and Jets. H. W. Liepmann. *GALCIT*, Aug., 1954. 24 pp. 10 refs. Theoretical study of aerodynamically created sound with considerations leading to a description of the noise field produced by boundary layers. The derived concept of induced velocities due to displacement effects is extended to flow in jets.

An Investigation of the Noise Produced by a Subsonic Air Jet. J. H. Gerrard. *J. Aero. Sci.*, Sept., 1956, pp. 855–866, 873. 15 refs. Measurements, over a wide frequency range and in 1/3-octave bands in this range, of the sound field of a 1-in. air jet issuing from a long pipe, with the mean Mach Number at the pipe orifice varying from 0.3 to 1.0, in order to determine the validity of the Lighthill predictions on aerodynamic sound. Examination of the dependence of the apparent position of the noise sources on frequency and jet speed and of the dependence of noise intensity upon jet speed in terms of the power relation $\bar{p}^2 \alpha M^n$.

An Analysis of Buzzing in Supersonic Ram Jets by a Modified One-Dimensional Nonstationary Wave Theory. Robert L. Trimpi. *U.S., NACA TN 3695*, July, 1956. 72 pp. Derivation of a theory applicable to the buzzing problem obtained by modification of the one-dimensional, unsteady-flow theory and introducing specified assumptions which greatly facilitate the computational efforts without impairing the usefulness of the theory for this type of flow.

Measurements on the Velocity of Sound in Air Under Pressures up to 20 Atm. Combined with Thermal Diffusion. A. Van Itterbeek and W. de Rop. *Appl. Sci. Res., Sect. A*, No. 1, 1956, pp. 21–28.

Propagation of Sound in Monatomic Gases. *U.S., NBS Sum. TR 2034*, July, 1956. 10 pp. Measurements (using a double-crystal interferometer with a number of design improvements) of the speed and attentuation of eleven-mc./sec. sound waves in helium, neon, argon, krypton, and xenon to provide new information on the behavior of gases under nonequilibrium conditions, permitting an intercomparison of propagation theories based on "classical" equilibrium assumptions with those based on modern kinetic concepts. Results are applicable to theories of nonuniform gases and to problems involved in upper-atmosphere flight, propagation of shock waves, and in general high-speed gas dynamics.

Aerodynamics

Aerothermodynamics

The Problem of Aerodynamic Heating. E. R. Van Driest. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 645.* 31 pp. 25 refs. Members, $0.65; nonmembers, $1.00. Analysis of the rate of heat transfer to the surface of high-speed vehicles.

An Investigation of the Effects of Heat Transfer on Boundary-Layer Transition on a Parabolic Body of Revolution (NACA RM-10) at a Mach Number of 1.61. K. R. Czarnecki and Archibald R. Sinclair. *U.S., NACA Rep. 1240*, 1955. 11 pp. 14 refs. Supt. of Doc., Wash. $0.20.

A Review of Heat Transfer Data on the Evaporation of Liquids at Sub-Atmospheric Pressures. T. D. Patten. *Gt. Brit. RAE TN Mech. Eng. 216*, Apr., 1956. 22 pp. 24 refs. Presentation of available data, particularly with regard to water and to the existing correlations of experimental results, and with special attention given to those theories of heat transfer during boiling which are likely to be encountered in practice. The study is directed toward the solution of the problem of cooling at high aircraft speeds through the possibility of rejecting the heat to a liquid as its latent heat of evaporation. Includes a graph compiled from existing data and applicable as a rough guide to the heat-transfer properties of boiling water.

Heat Transfer in Compressible Laminar Boundary Layers. II. S. Lal. *J. Aero. Soc. India*, May, 1956, pp. 19–34. Development of similarity equations (when specific pressure gradients are known) formed by a suitable combination of the independent variables such that partial differential equations governing boundary-layer flow can be reduced to a system of ordinary differential equations.

Calculations of Laminar Heat Transfer Around Cylinders of Arbitrary Cross Section and Transpiration-Cooled Walls with Application to Turbine Blade Cooling. E. R. G. Eckert and J. N. B. Livingood, *U.S., NACA Rep. 1220*, 1955. 21 pp. Supt. of Doc., Wash, $0.25. Development of an approximate method for the determination of flow and thermal boundary layers around cylinders with transpiration-cooled walls using the von Kármán integrated momentum equation and an analogous heat-flow equation.

Engineering Relations for Heat Transfer and Friction in High-Velocity Laminar and Turbulent Boundary-Layer Flow Over Surfaces with Constant Pressure and Temperature. E. R. G. Eckert, (*ASME Diamond Jubilee Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Aug., 1956, pp. 1,273–1,283. 29 refs.

Turbulent - Heat - Transfer Measurements at a Mach Number of 3.90. Maurice J. Brevoort. *U.S., NACA TN 3734*, July, 1956. 15 pp. Experimental investigation using an axially symmetric annular nozzle consisting of an inner, shaped center body and an outer cylindrical sleeve.

Surface-Protection and Cooling Systems for High-Speed Flight. D. J. Masson and Carl Gazley, Jr. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 638.* 19 pp. 13 refs. Members, $0.50; nonmembers, $0.85. Discussion of cooling systems for aircraft under transient and continuous heat inputs.

The Thermal Problems of High-Speed Flight and the General Electric Aircraft Cooling Program. J. W. Rizika. *ASME Semi-Annual Meeting, Cleveland, June 17–21, 1956, Paper 56—SA-24.* 11 pp. Review of the problems including aerodynamic heating, internal heat sources, and heat sinks, with a discussion of the objectives and some of the conclusions.

Diffusion Effects in a Binary Isothermal Boundary Layer. E. R. G. Eckert and P. J. Schneider. *U. Minn. Inst. Tech. Dept. Mech. Eng. TR 5 (OSR TN 55–258)*, Nov., 1955. 15 pp. Evaluation of the mass-transfer cooling method. Similarity solutions are obtained for plane longitudinal flow over a flat porous plate with normal injection of a fluid whose variable properties are widely different from those of the main stream.

Tip-Bluntness Effects on Cone Pressures at $M = 6.85$. Mitchel H. Bertram. *J. Aero. Sci.*, Sept., 1956, pp. 898–900. Experimental investigation to examine the aerodynamic effect of a simple type of nose blunting on a basic body, taking into account the thermodynamic aspect.

Boundary Layer

Some Problems in Boundary-Layer Transition. J. A. Steketee. *UTIA Rep. 38*, Apr., 1956. 105 pp. 46 refs. Theoretical investigation, using models which illustrate some aspects of the reality, to establish the existence of regions of turbulent flow clearly distinguished from, and surrounded by, laminar flow and to determine the way in which these regions grow and are transported, in order to provide analytical support for the empirical facts forming the basis for the Emmons theory of boundary-layer transition.

Asymptotic Suction Characteristics of the Boundary Layer Over a Circular Cylinder. H. G. Lew. *J. Aero. Sci.*, Sept., 1956, pp. 895–897. OSR-supported theoretical investigation.

Méthodes de Calcul de la Couche Limite Laminaire Bidimensionnelle en Régime Compressible. E. A. Eichelbrenner. *France, ONERA Pub. 83*, 1956. 135 pp. 28 refs. In French. Development of methods for the calculation of the laminar two-dimensional boundary layer in a compressible fluid, with an analysis of the initial conditions related to the problem of the boundary layer behind a detached shock wave and with a discussion of mathematical aspects of the problem.

An Evaluation of Four Experimental Methods for Measuring Mean Properties of a Supersonic Turbulent Boundary Layer. George J. Nothwang. *U.S. NACA TN 3721*, June, 1956. 34 pp. Analytical results of surveys made through a turbulent boundary layer on a flat plate, at one longitudinal station on the plate, by means of a pitot probe, an X-ray densitometer, and hot-wire probes, with tests conducted in an 8- by 8-in. supersonic nozzle at free-stream Mach Number of 3.03 and Reynolds Number of approximately 210,000 based on boundary-layer thickness.

Strato Limite Attorno ad una Lastra Piana Investita da un Fluido Incompressibile Dotado di una Velocità che è Somma di una Parte Costante e di una Parte Alternata. Silvio Gibellato. (*Atti Accad. Sci. Torino*, 1955-1956.) *Torino Polytech. Inst., Aero. Lab., Monographs 352, 365*; 1955, 1956. 13, 12 pp. In Italian. Investigation of the boundary layer on a flat plate in incompressible flow at partly constant and partly alternate velocities.

Elementarer Existenzbeweis für die Grenzschichtströmung an einer Klasse rotierender Körper. Theo Geis. *ZAMM*, May-June, 1956, pp. 222–229. In Ger-

man. Analysis of the problem of finding the boundary-layer flow on bodies of revolution of a certain shape rotating about their own axis in otherwise undisturbed fluid.

Décollement Laminaire en Deux Dimensions; Confrontation Entre Théorie et Expérience. E. A. Eichelbrenner and H. Werlé. *La Recherche Aéronautique*, May-June, 1956, pp. 11–18. In French. Comparison of experimental results obtained from tests in the Chatillon hydrodynamic tunnel with calculations of the point of laminar separation and of the velocity profiles in the boundary layer located immediately downstream of the separation, obtained by using the Polhausen method.

Versuche über die Beeinflussung der Grenzschicht am Tragflügel. *Luftfahrttechnik*, Oct. 15, 1955, pp. 109–111. In German. Analysis of existing methods of boundary-layer control and of a tentative modification program.

Untersuchungen über die Abhängigkeit des Umschlages laminar-turbulent von der Oberflächenrauhigkeit und der Druckverteilung. E. G. Feindt. *DFL Inst. Aero., Bericht No. 56/10*, Apr. 17, 1956. 167 pp. In German. Experimental investigation to determine the manner in which the location of the laminar-turbulent transition point depends on pressure gradient and surface roughness in the case of flow along a wall with three-dimensional roughness elements and flow along a wall with a two-dimensional individual roughness element.

Grenzschicht-Steuerung zur Vermeidung der Ablösung und zur Erzielung geringen Luftwiderstandes. G. V. Lachmann. *Flugwelt*, May, 1956, pp. 290–292, 294. In German. Study of boundary-layer control for avoiding the separation and diminishing the drag.

Control Surfaces

An Investigation of Forward-Located Fixed Spoilers and Deflectors as Gust Alleviators on an Unswept-Wing Model. Delwin R. Croom, C. C. Shufflebarger, and Jarrett K. Huffman. *U.S., NACA TN 3705*, June, 1956. 26 pp. Evaluation of forward-located fixed spoilers, deflectors, or a spoiler-deflector combination to determine their static longitudinal aerodynamic characteristics and gust alleviation capabilities. Results show that the lift-curve slopes are fairly linear and substantially reduced by the addition of either the spoiler or the deflector configuration. The slope, however, is nonlinear for the spoiler-deflector combination.

Practical Work on "Flap-Blowing"; Modified de Havilland Sea Venom Mk. 21 with Especially Adapted de Havilland Ghost Engine; First Trials of "Flap-Blowing" on a British Aircraft Carrier. *de Havilland Gazette*, June, 1956, pp. 80, 81.

Fluid Mechanics & Aerodynamic Theory

Transport Properties for Binary Gas Mixtures. W. O. Carlson and P. J. Schneider. *U. Minn. Inst. Tech. Dept. Mech. Eng. TR 7 (OSR TN 56-45)* Jan., 1956. 46 pp. 14 refs. Review of various methods for calculating transport proper-

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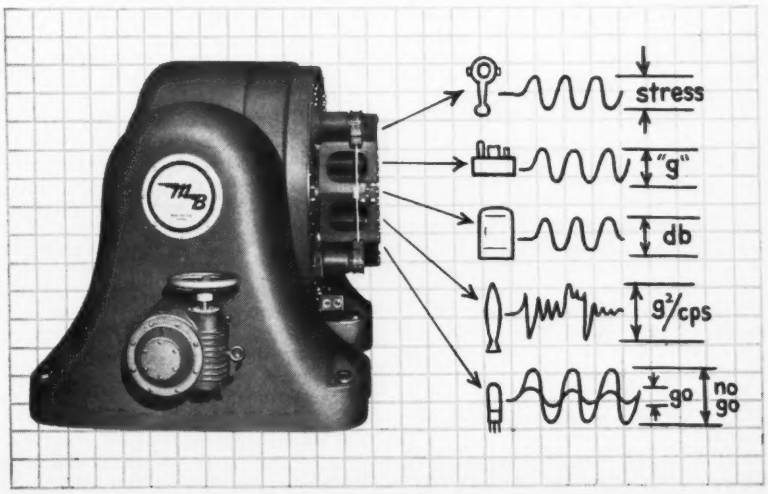

ties to select or develop the most rapid method of calculating these properties over a full range of mixture concentrations and a wide range of mixture temperatures.

Experiments on Two Dimensional Base Flow at M = 2.4. L. Fuller and J. Reid. *Gt. Brit. RAE Rep. Aero. 2569*, Feb., 1956. 50 pp. Tests on a family of two-dimensional afterbodies to determine the effects of boattail angle and internal flow on the base pressure, afterbody pressure, and velocity distribution in the wake.

Scambi di Quantità di Moto, di Calore e di Massa fra Correnti di Miscele Gas-Vapore e Superfici Bagnate. Gianni Jarre. (*Atti Accad. Sci. Torino*, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 364*, 1956. 21 pp. In Italian. Derivation of equations related to the fields of velocity, concentration, and enthalpy in a mass of gas vapors, with a discussion of the mixing process, and the mass and heat transfer between a uniform gas flow and a wetted surface formed by the liquid or solid phase of the vapor.

Preliminary Report on a Study of Separated Flows in Supersonic and Subsonic Streams. Dean R. Chapman, Donald M. Kuehn, and Howard K. Larson. *U.S., NACA RM A55L14*, June 12, 1956. 15 pp. 10 refs. Results of theoretical and experimental investigations, with measurements for a variety of two-dimensional shapes and observation of the overall pressure rise to the separation point and to the first peak pressure in flows where sizable separated regions exist. The location of transition relative to the reattachment and the separation conditions is taken into account.

Spherical, Cylindrical and One-Dimensional Gas Flows. Joseph B. Keller. *Quart. Appl. Math.*, July, 1956, pp. 171–184. Formulation of the problem of spherical, cylindrical, or planar flow of a polutropic gas in Lagrangian variables, giving rise to a nonlinear second-order partial differential equation in two variables h and t. Derivation of a class of special solutions of this equation by separation of variables depending upon an arbitrary function which is related to the arbitrary entropy distribution in the gas. Application of the solution to the propagation of finite and strong shocks in variable media.

Preliminary Low Speed Wind Tunnel Tests on Flat Plates and Air Brakes: Flow, Vibration and Balance Measurements. R. Fail, T. B. Owen and R. C. W. Eyre. *Gt. Brit., ARC CP 251* (Jan., 1955), 1956. 45 pp. BIS, New York, $1.08. Includes flow measurements behind sharp-edged flat plates (a) at 90° for various shapes and (b) for a square plate over an incidence range; and lift, drag, and pitching-moment increment measurements on a square plate mounted (c) on a long cylinder and (d) near the end of several shapes of rear fuselage.

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The Flow Past an Unswept- and a Swept-Wing-Body Combination and Their Equivalent Bodies of Revolution at Mach Numbers Near 1.0. Walter F. Lindsey. *U.S., NACA TN 3703*, June, 1956. 18 pp. Tests using the schlieren method of flow visualization to provide data for comparison.

Sulla Determinazione della Forma Esterna del Condotto di Rotazione di Minima Resistenza, per Determinate Condizioni Poste alla Linea Meridiana, in Corrente Supersonica Linearizzata. Carlo Ferrari. (*Mem. Accad. Sci. Torino, Ser. 3, Vol. A, Pt. 1.*) *Torino Polytech. Inst., Aero. Lab., Monograph 360*, 1955. 56 pp. In Italian. Determination of the external contour of a body of revolution of minimum drag for obtaining conditions at stations along the meridian line in linearized supersonic flow.

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Study of Hydrodynamic Parameters for Design of a Strut Suitable for Electromagnetic Rodmeter. M. P. Burkart and M. S. Macovsky. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 1027*, Mar., 1956. 18 pp. 10 refs. Experimental investigation of various modifications to a strut having an EPH-section profile in order to determine their effectiveness in stimulating boundary-layer transition without appreciably lowering the speed of incipient cavitation, and of the vortex excitation characteristics of struts, with results extrapolated to cover the full operating speed range of the rodmeter.

A Review of the Hypersonic Research Carried Out at Princeton University from 1949–1955. S. M. Bogdonoff. *USAF WADC TR 55–211*, Mar., 1956. 13 pp. 17 refs. Summary of theoretical and experimental studies on the effects of viscosity at hypersonic speeds with test results obtained at Mach Numbers between 11 and 15. Also includes studies on the effects of condensation and description of hypersonic wind tunnels.

Variational Method in the Theory of Axisymmetric Rotational Flow of a Compressible Fluid. Bohdan Krajewski. *J. Aero. Sci.*, Sept., 1956, pp. 891, 892.

The Rotational Field Behind a Curved Shock Wave Calculated by the Method of Flux Analysis. Shigeo Uchida and Michiru Yasuhara. *J. Aero. Sci.*, Sept., 1956, pp. 830–845. 34 refs.

Shock-Turbulence Interaction and the Generation of Noise. Appendices A, B—**Complete Velocity Spectrum Tensor.** Appendix C—**Calculations for Axisymmetric Initial Turbulence.** H. S. Ribner. *U.S., NACA Rep. 1233*, 1955. 19 pp. 14 refs. Supt. of Doc., Wash. $0.25. Analysis of a convected field of turbulence with a shock wave, including data for modified turbulence, entropy spottiness, and noise generated downstream of the shock.

An Introduction to the Use of the Shock Tube for the Determination of Physico-Chemical Parameters. S. S. Penner, F. Harshbarger, and V. Vali. *GALCIT AF 18(603)-2 TR 1*, June, 1956. 24 pp. Analysis of applications of the shock tube at elevated temperatures, including a qualitative survey of shock-tube development describing the principles and performance of various designs, a survey of optical techniques suitable for shock-tube studies, and a summary of representative determinations of physicochemical parameters behind incident and reflected shock waves. The applicability of the shock tube as a research tool for studies of processes related to combustion reactions is pointed out.

Gas-Dinamica Transonica. Silvio Nocilla. (*R. C. Accad. Nazl. Lincei, Classe Sci. Fis. Mat. et Nat., Ser. 8*, Jan., 1955.) *Torino Polytech. Inst., Aero. Lab., Mono-*

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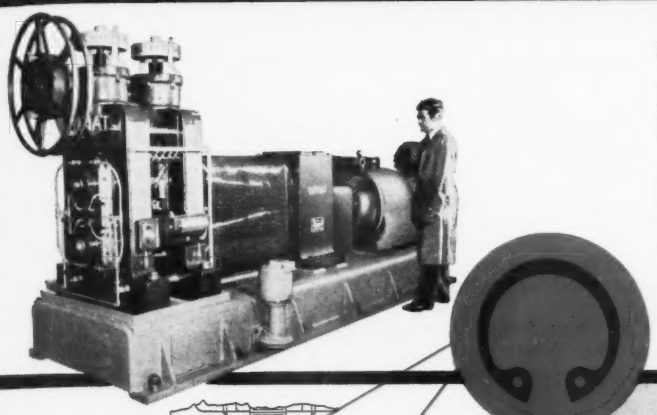

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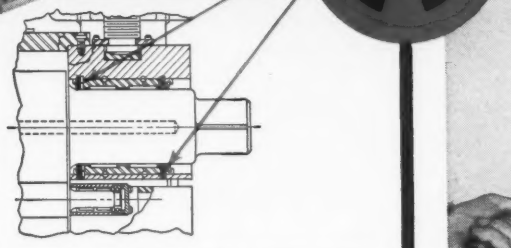

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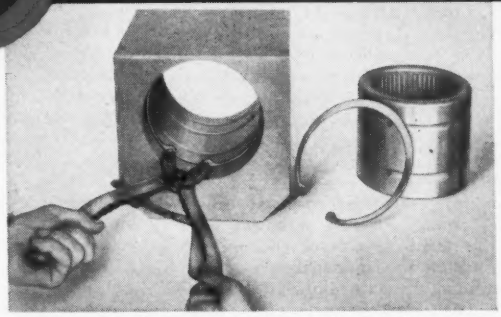

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graph 350, 1955. 7 pp. In Italian. Discussion of the solution of the Tomotika-Tamada equation for transonic flow.

Sur la Turbulence Spatialement Homogène d'un Fluide Compressible. Maria Z. Krzywoblocki. *France, Min. de l'Air PST 314*, 1956. 54 pp. 10 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 650. In French. Generalization of the Dampé theory, taking into account the von Kármán, Kolmogoroff, Heisenberg, and Onsager theories.

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Alternating Pressures and Blade Stresses in an Axial Flow Compressor. Appendix I—**Derivation of Relation Between Pressure on a Blade Section and the Pressure in the Compressor Annulus.** J. R. Forshaw, H. Taylor, and R. Chaplin. *Gt. Brit., ARC R&M 2846* (June, 1951), 1956. 29 pp. BIS, New York, $1.44. Experimental investigation to determine the origin of the forces exciting vibration in an axial-flow compressor and their magnitude relative to the calculated gas bending loads. The blade stresses resulting from these forces are measured, and a value is obtained for the energy input to a blade when vibrating in the predominant modes under running conditions.

Stall Propagation in Axial-Flow Compressors. Appendix A—**Calculation of Cascade Discharge Coefficient for Real Cascade.** Appendix B—**Stall Propagation Velocity in Polar Coordinates.** Appendix C—**Stall Propagation Velocity with Flow Into a Continuum.** Alan H. Stenning, Anthony R. Kriebel, and Stephen R. Montgomery. *U.S., NACA TN 3580*, June, 1956. 83 pp. 11 refs. Derivation of a theory based on the assumption that the flow behind the cascade consists of free jets discharging into a constant-pressure region. The effects of finite blade chord and of the boundary-layer response to changes in angle of attack are taken into account, and the theory is valid for small perturbations in velocity about a mean flow condition with finite pressure rise across the cascade, provided that the pressure fluctuations downstream of the cascade are much smaller than those upstream.

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Analiza Przeplywu Przez Stopień Sprężarki Osiowej. Bohdan Krajewski. *Tech. Lotnicza*, Jan.-Feb., 1956, pp. 2–5. In Polish. Analysis of the flow through one stage of an axial compressor.

A Potential Flow Solution with Applications in Studies Concerning Mass Addition Along the Boundaries of the Flow. J. Leith Potter and Norman M. Shapiro. *USRA OML Rep. 2R16F*, June 18, 1956. 17 pp. Analysis of a system where mass is added from the opposite walls of a two-dimensional container or chamber which is closed at one end and open at the other, using potential flow methods.

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Turbulent Flow in the Entrance Region of a Pipe. Donald Ross. *Trans. ASME*, July, 1956, pp. 915–923. 16 refs. Abridged. Navy-supported derivation of an analytical solution for the turbulent boundary-layer flow. Equations yield the relative momentum thickness at any station within ten diameters of the entrance, and from this the pressure drop and head loss are calculated.

A Study of the High-Speed Performance Characteristics of 90° Bends in Circular Ducts. James T. Higginbotham, Charles C. Wood, and E. Floyd Valentine. *U.S., NACA TN 3696*, June, 1956. 28 pp. Investigation of the performance of four bends in ducts of constant diameter with ratios of radius of curvature to diameter of 0.75, 1.00, 2.50, and 4.00 over a range of inlet Mach Numbers extending up to the choking condition for both thin and thick inlet boundary layers.

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Measurements of Attenuation of Compression Waves of Finite Amplitude in Air and Evaluation of the Coefficient of Friction. J. A. Owczarek. *Quart. J. Mech. & Appl. Math.*, June, 1956, pp. 164–184.

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The Free Streamline Method Applied to the Flow at the Rear of a Duct. Appendix—**The 'Free Streamline' Method Applied to the Flow at the Rear of a Two-Dimensional Duct.** A. H. Craven. *Coll. of Aeronautics, Cranfield, Rep. 99*, Mar., 1956. 24 pp. Determination of complex potentials for the jet flow and the flow in the free stream, resulting in a calculation of the equation for the wake streamline and the velocity and pressure distributions. Includes consideration of the corresponding axisymmetric problem.

Analytic Determination of Two-Dimensional Supersonic Nozzle Contours Having Continuous Curvature. James C. Sivells. *USAF AEDC TR 56-11*, July, 1956. 29 pp. Methods of determining coordinates for perfect-fluid contours downstream of the inflection point in a supersonic nozzle.

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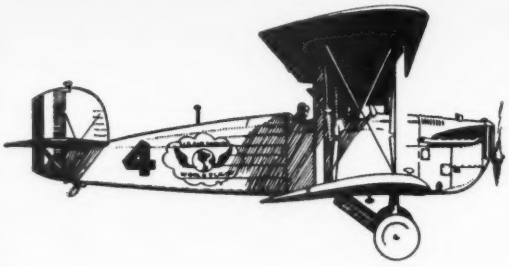

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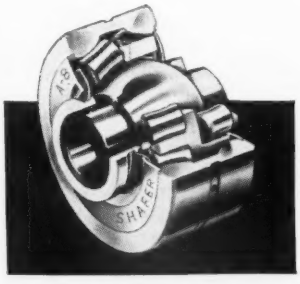

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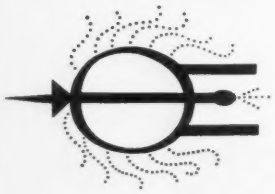

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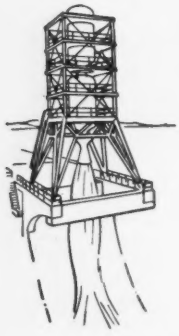

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Some Tests on the Spread of Velocity in a Cold Jet Discharging with Excess Pressure from a Sonic Exit into Still Air. J. Seddon and L. Haverty. *Gt. Brit., ARC CP 246* (Nov., 1955), 1956. 15 pp. BIS, New York, $0.45.

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Performance

Phase IV Performance Test of the F-86F-40 Airplane Equipped with 6 × 3-Inch Leading Edge Slats and 12-Inch Extensions on the Wing Tips. Norris J. Hanks and Loren W. Davis. *USAF FTC TR 56-12*, May, 1956. 44 pp. Results indicate the achievement of a reduction in take-off and landing speeds and in runway requirements, substantial improvement in maneuvering capability at altitudes above 25,000 ft., and an increase in combat range and high speed, without creating any undesirable characteristics.

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The Dynamic-Response Characteristics of a 35° Swept-Wing Airplane as Determined From Flight Measurements. William C. Triplett, Stuart C. Brown, and G. Allan Smith. *U.S., NACA Rep. 1250*, 1955. 25 pp. Supt. of Doc., Wash. $0.25. Comparison of data obtained at 35,000 ft. in the Mach Number range of 0.50 to 1.04 and at 10,000 ft. with predictions based on theoretical studies and wind-tunnel experiments.

Preliminary Investigation of the Effects of External Wing Fuel Tanks on Ditching Behavior of a Sweptback-Wing Airplane. Ellis E. McBride. *U.S., NACA TN 3710*, July, 1956. 21 pp.

Investigation of Lateral Control Near the Stall; Analysis for Required Longitudinal Trim Characteristics and Discussion of Design Variables. Fred E. Weick and Norman Abramson. *U.S., NACA TN 3677*, June, 1956. 91 pp. 12 refs. Development of analytical means for the estimation of the elevator deflection required to trim in steady longitudinal flight and for the demonstration in a quantitative manner of the effects on longitudinal trim of changes of some design parameters. Simplified methods and semiempirical data are summarized to provide analytical procedures applicable to preliminary design. Two light aircraft are analyzed quantitatively for both power-on and power-off conditions in order to demonstrate the use of these methods and to provide a comparison with flight-test results.

Investigation of Lateral Control Near the Stall; Flight Tests with High-Wing and Low-Wing Monoplanes of Various Configurations. Fred E. Weick and H. Norman Abramson. *U.S., NACA TN 3676*, June, 1956. 34 pp. Results indicate that, for all the light aircraft tested, adequate lateral control is available up to a critical angle of attack which is within 2° of the angle of attack for maximum lift.

Wings & Airfoils

A Method for Calculating the Pressure Distribution Over Jet-Flapped Wings. D. Kuchemann. *Gt. Brit., RAE Rep. Aero. 2573*, May, 1956. 38 pp. 18 refs. Analysis based on Spence's calculation of circulation and chordwise loading of a jet-flap system to find the pressure distribution when the external lift force and the jet momentum are known.

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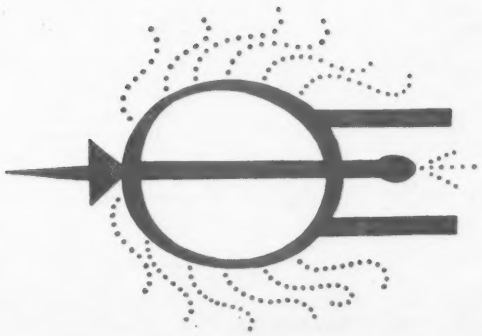
Campi di Moto Transonici Attorno a Profili Alari Simmetrici, Senza Incidenza,



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con Numero di Mach I. Silvio Nocilla. (*Atti Accad. Sci. Torino*, 1955–1956.) *Torino Polytech. Inst., Aero. Lab., Monograph 367*, 1956. 17 pp. In Italian. Study of the transonic flow around symmetrical wing profiles without incidence at $M=1$.

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The Effect of Wing Plan Form on the Downwash Behind Wings. Akira Mitsuyasu. *J. Japan Soc. Aero. Eng.*, June, 1956, pp. 1–5. In Japanese. Calculation of theoretical downwash angles and their comparison with experimental results.

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Quasi-Cylindrical Theory of Wing-Body Interference at Supersonic Speeds and Comparison with Experiment. Appendix A—Decomposition of Boundary Conditions of Wing-Body Combination. Appendix B—Asymptotic Span Loading for First Harmonic; Wing-Incidence Case. Appendix C—Determination of Wing-Alone Potential for Angle-of-Attack Case. Jack N. Nielsen. *U.S., NACA Rep. 1252*, 1955. 56 pp. 25 refs. Supt. of Doc., Wash, $0.55.

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Vibrațiile Avionului. J. Grosvald. *Rev. Transporturilor,* Mar., 1956, pp. 119–125. In Rumanian. Study of vibration phenomena in aircraft.

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The Integral Equations of Aeroelasticity. Appendix I—**Experimental Determination of Influence Functions for a Swept Wing.** Appendix II—**Remarks on the Use of Hamilton's Principle.** J. R. M. Radok. *Australia, Aero. Res. Comm. Rep. ACA-56,* May, 1955. 32 pp. 14 refs. Formulation of a unified theory of all aeroelastic phenomena based on the derivation of equations of equilibrium.

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Flutter Calculations on a Rudder with Trailing-Edge Spoiler. Ll. T. Niblett. *Gt. Brit., RAE Rep. Struc. 202,* May, 1956. 13 pp. Calculations of flutter on two different spoiler systems and comparison with flight tests.

Some Wind-Tunnel Experiments on Single-Degree-of-Freedom Flutter of Ailerons in the High Subsonic Speed Range. Sherman A. Clevenson. *U.S., NACA TN 3687,* June, 1956. 32 pp. Results of wind-tunnel tests on three wing models with various aileron configurations. Density in the range of 0.08 $\times 10^{-2}$ to 0.58 $\times 10^{-2}$ slug per cu.ft. is found to have little effect on the initial amplitude or initial Mach Number associated with the aileron oscillations.

Safeguards Against Flutter of Airplanes. Appendix I—**Compilation of Some General Conceptions Concerning Vibrations.** Appendix II—**Aileron Vibrations of High-Speed Aircraft.** Appendix III—**Calculation of the Dynamic Balancing of a Surface; Dynamic Balancing.** Appendix IV—**Influence of the Various Parameters on the Critical Speed.** Appendix V—**Examples of the Achievement of Balanced Control Surfaces.** Gerhard De Vries. (*La Recherche Aéronautique,* No. 12, 13; 1949, 1950). *U.S., NACA TM 1423,* Aug., 1956. 94 pp. Translation.

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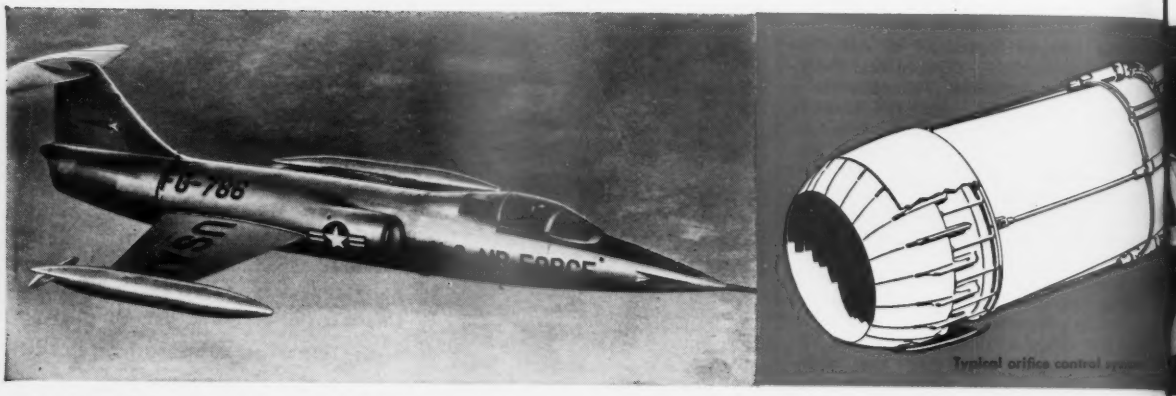

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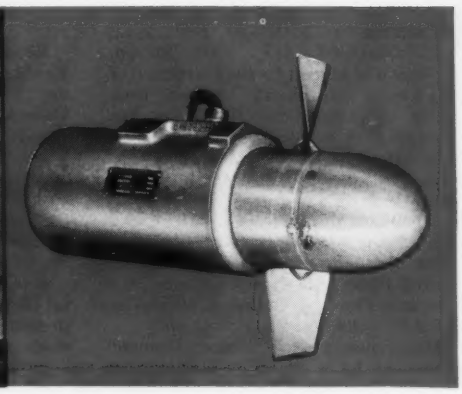

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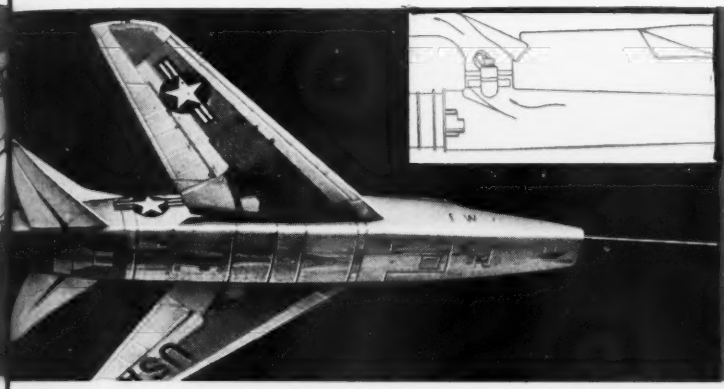

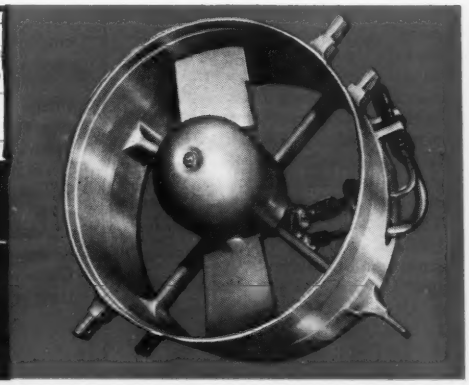

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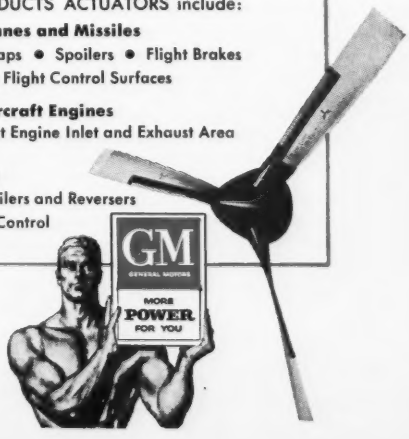

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The Effect of Wing Torsion on Aileron-Tab Flutter. H. Hall. *Gt. Brit., RAE Rep. Struc. 203*, Apr., 1956. 31 pp. Derivation of criteria for the prevention of wing-torsion - aileron-tab flutter from results of calculations based on the assumption of an idealized ternary type spring-tab system having degrees of freedom in wing pitch, rotation of the control surface, and rotation of the tab. Includes comparison of results with those obtained by Wittmeyer and Templeton.

The Flutter of a Two-Dimensional Buckled Plate with Clamped Edges in a Supersonic Flow. J. G. Eisley. *GALCIT OSR TN 56–296*, July, 1956. 40 pp.

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Aeroelastic Problems in Connection with High-Speed Flight. E. G. Broadbent. *J. RAeS*, July, 1956, pp. 459–475. 20 refs. Review of the developments in the field of aeroelasticity during the past 10 years with emphasis on the problems induced by increasing Mach Number. Problems considered include the use of thinner airfoils which require a greater stiffness, and the uncertainty of the calculations for flutter coefficients.

Methods for Calculating Pressure Distributions on Oscillating Wings of Delta Type at Supersonic and Transonic Speeds. F. Hjelte. *Stockholm, KTH AERO TN 39*, 1956. 29 pp. 16 refs.

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Experimental Measurements of Forces and Moments on a Two-Dimensional Oscillating Wing at Subsonic Speeds. Appendix A—**Determination of the In-phase Moment and the Center-of-Pressure Shift.** Appendix B—**Dynamic Magnification of Lift Force.** Sherman A. Clevenson and Edward Widmayer, Jr. *U.S, NACA TN 3686*, June, 1956. 28 pp. Results of wind-tunnel tests, including a few data in the transonic region and a description of an experimental method applicable to the transonic region.

Lift and Moment Coefficients for an Oscillating Rectangular Wing-Aileron Configuration in Supersonic Flow. Appendix A—**Coefficients Associated with Wing Motion.** Julian H. Berman. *U.S., NACA TN 3644*, July, 1956. 46 pp. 13 refs. Analysis using the linearized theory for compressible unsteady flow to treat the problem of a partial-span rectangular control surface, hinged at its leading edge and mounted on a rectangular wing oscillating in supersonic flow. The motions of the wing-aileron configuration are assumed to consist of vertical translation, pitching, and aileron rotation.

Theoretical Requirements of Tunnel Experiments for Determining Stability Derivatives in Oscillatory Longitudinal Disturbances. Appendix—**Equations of Dynamic Stability for Level Flight with Derivatives of Oscillatory Motion.** S. Neumark and A. W. Thorpe. *Gt. Brit., ARC R&M 2903* (June, 1950), 1955. 14 pp. BIS, New York, $0.81.

Response of Accelerated Free-Flight Fin-Stabilized Rockets to Wind. Appendix I—**Mathematical Development of General Solution.** S. M. Robinson. *Douglas Rep. SM-18443*, Oct. 26, 1955. 23 pp. Army-sponsored derivation of the equations of motion for an accelerated rocket in the presence of a uniformly fluctuating wind, developed in simplified form with distance traveled as an independent variable. A solution in general form for the flight path angular response of the rocket to the impressed wind is presented, and solutions for three special cases and development of the rocket admittance function are included.

Aeronautics, General

The Aerodynamic Art (The 44th Wilbur Wright Memorial Lecture). William S. Farren. *J. RAeS*, July, 1956, pp. 431–449. Review of transonic flow problems and discussion of some of the solutions obtained.

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The Next 25 Years in Canadian Aviation. *AVRO Rep.*, Feb., 1956. 30 pp. Discussion of probable developments in aviation and the aircraft industry in Canada within the next 25 years and of their effect on Canadian economy.

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A Look Ahead at Air Transportation. T. P. Wright. *Radio Tech. Comm. Aeronautics, Assembly Meeting, Buffalo, June 7, 1956, Paper.* 12 pp. Discussion of some of the problems to be faced by air transportation in the next few years, including the size of the market, electronics, airports, and technological progress.

The Economic Aspects of Jet Transport. Armin Baltensweiler. *Interavia*, No. 4, 1956, pp. 244–247. Discussion of operational and terminal costs by graphical comparison of present-day air liners with jet transports; criteria include travel times and pay load of different aircraft, percentage breakdown of direct operating costs per ton-kilometer, fuel costs per ton-kilometer plotted against operating distance, direct operating losses plotted against number of unproductive flying hours per year, and direct operating costs per ton-kilometer plotted against annual number of flying hours and operating distance.

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Massstäbe zur Beurteilung der Wirtschaftlichkeit von Luftverkehrsunternehmen. Heinz Röhm. *Nordrhein-Westfalen, Wirtsch. & Verkehrsmin., Tech. Bericht No. 29*, 1954. 43 pp. In German. Criterion for estimating economic efficiency in air transport.

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Special Issue: Commercial Aircraft; Airliners of the World. *Flight*, July 6, 1956, pp. 9–72, cutaway drawings. Specifications, cost, and performance figures for 23 commercial aircraft. Includes a description of air frame, power plants, systems, accommodations, and commercial history for each type.

The Wyvern Story. *The Aeroplane*, June 15, 1956, pp. 549–556, cutaway drawing. Discussion of the Westland strike-fighter, including developmental history, structural details, and performance data.

De Havilland's New Comet. *The Aeroplane*, July 6, 1956, pp. 12–17, cutaway drawing. Discussion of the design, structural, and aerodynamic characteristics of the Comet 4 aircraft. Includes a description of the hydraulic, electrical, and control systems, and of the control-cabin layout.

Aerodynamics of the Douglas DC-8. *The Aeroplane*, June 22, 1956, pp. 590–592. Discussion of aerodynamic design characteristics of the DC-8, including the introduction of a special inverted camber airfoil with the inner 25 per cent of the wing span to ensure root stall, curved engine nacelle pylons which are cambered so as to lie along flow streamlines, double-slotted flaps equipped with spoilers and torque-link connected outboard ailerons.

Essais de Largage de Verrières Dans la Soufflerie S_1 de Modane Avrieux. S. Schneider. *La Recherche Aéronautique*, May-June, 1956, pp. 27–29. In French. Description of a new technique used in the Modane S_1 wind tunnel for canopy release tests.

Recommendations on Cockpit-Visibility Standards for Transport-Type Aircraft. *U.S., CAA TDR 275*, Feb., 1956. 6 pp. Application of data obtained from pilot observations, pilot eye-movement study, collision-course study, and development of a binocular camera for recording cockpit visual angles.

An Experimental Study of Applied Ground Loads in Landing. Benjamin Milwitzky, Dean C. Lindquist, and Dexter M. Potter. *U.S., NACA Rep. 1248*, 1955. 34 pp. Supt. of Doc., Wash, $0.30. Investigation of the applied ground loads and the coefficient of friction between the tire and the ground during the wheel spin-up process in impacts of a small landing gear under controlled conditions on a concrete landing strip in the Langley impact basin, with supplementary tests to evaluate the drag-load alleviating effects of prerotating the wheel before impact so as to reduce the relative velocity between the tire and the ground.

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On Landing Gear Stresses. A. Gentric. (*Docaero No. 25*, Jan., 1954, pp. 17–38.)

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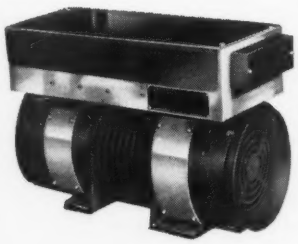

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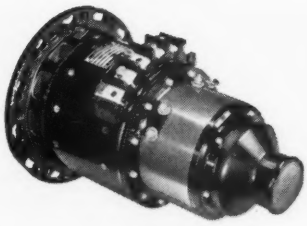
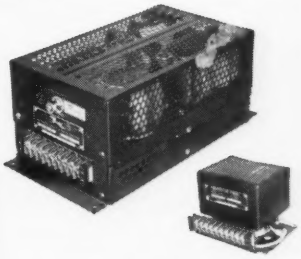
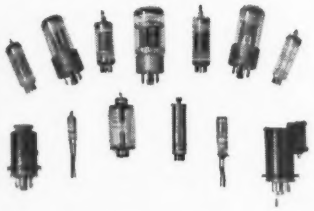


High-Temperature
AC GENERATORS



AC Voltage Regulators
(Magnetic Amplifier Type)
and
SYSTEM COMPONENTS



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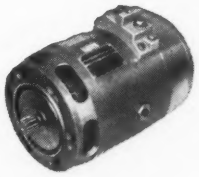
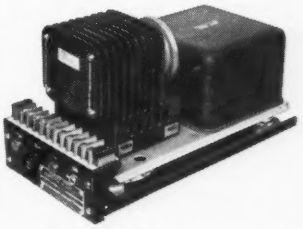


High-Temperature
DC GENERATORS



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U.S., NACA TM 1422, July, 1956. 45 pp. Translation. Investigation of vibratory phenomena in landing gear. Descriptions are given of two test installations—a toboggan and a vertical drop test machine. The analysis takes into account tangential forces applied to landing gears, the inflation pressure of the tires, the sliding velocity, the nature of rubber in the tire, and the characteristics of the ground.

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The Physiological Basis of Protection Afforded by Clothing. Grandpierre and Biget. (*Rev. Corps Santé Mil.*, 1952, pp. 27–39.) *Gt. Brit., RAE Lib. Transl. 563*, Apr., 1956. 13 pp. Description of a theoretical method for predicting clothing requirements under given conditions or for estimating in advance the protection value of clothing already issued, in which the thermal insulating capacity is measured in terms of "clos" (units of thermal insulation), "tolerance time," or a combination of both.

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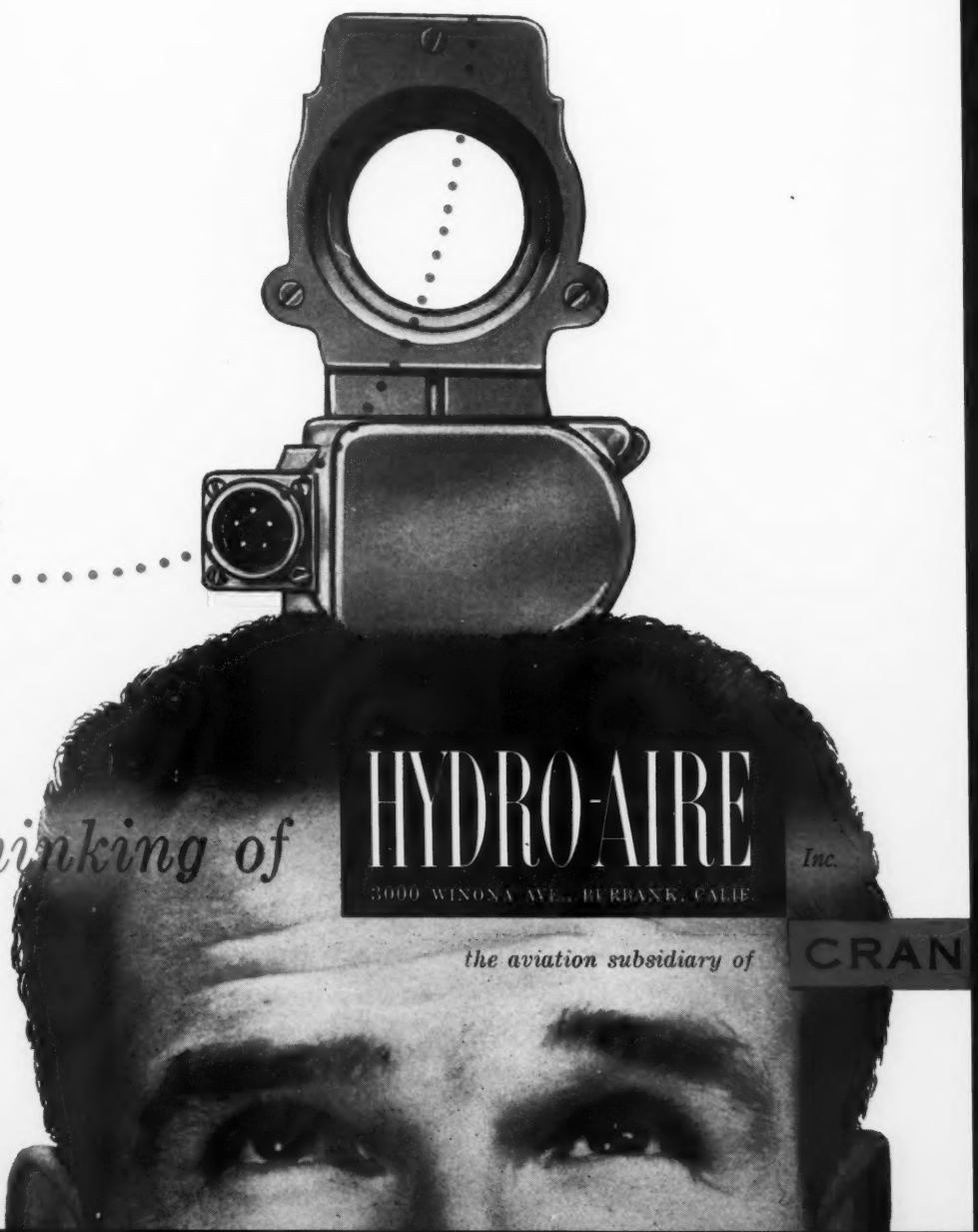

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"Mnemonic Morons"; The Automatic Digital Computer as a Research Tool. David Feign. *Res. Trends (Cornell Aero. Lab.)*, Spring, 1956, pp. 5–7. General developmental explanation of the fundamental construction, the advantages, and the applications of digital computers, including the reduction of wind-tunnel data, flight data reduction, matrix calculations, and the "Monte Carlo" method.

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The Effect of the Differential Selection of Target Study Cues Upon Aiming Point Identification Test Performance. G. Raymond Stone. *USAF PTRC TN 56-40*, Feb., 1956. 8 pp.

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Electronics Buyers' Guide Issue. *Electronics*, June Mid-Month, 1956. 1,042 pp. Comprehensive alphabetical listings of components and allied electrical products, manufacturers, registered trade names, and distributors. Partial contents of Reference Sheet Section: VHF Transmission Line Calculator, A. E. Sanderson. Normalized Filter Design, Samuel D. Bedrosian and R. McCoy, Jr. Delay Line Design, Joseph F. Sodaro. Power Rating Parasitic Suppressors, Joseph A. Huie. Characteristics of Computers and Storage Devices, John M. Carroll. Notch Network Design, C. J. Savent, Jr., and C. A. Savent. Transistor Characteristics for Circuit Designers, Seymour Schwartz. Standard Symbols for Electronics.

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Inter-Reciprocity Applied to Electrical Networks. J. L. Bordewijk. *Appl. Sci. Res., Sect. B*, No. 1–2, 1956, pp. 1–74. 28 refs. Extension of the concept of reciprocity to a new concept called inter-reciprocity which applies to both reciprocal and nonreciprocal structures. For electrical network investigations a unique topological concept called transposition has been devised in such a manner that a network and its transpose are interreciprocal. Applications are made to feedback amplifiers, two-pole noise in tubes, and transistor circuits.

Semiconductor Power Rectifiers in Continuous-Duty Circuits. F. W. Gutzwiller. *Elec. Mfg.*, July, 1956, pp. 109–111, 250–254. Discussion of design considerations for small electrical losses in germanium and silicon rectifiers considering heat generation and dissipation factors.

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An Investigation Into the Transmission of Data Over a Teleprinter Link. A. Cohen. *Gt. Brit., RAE TN TD 2*, Jan., 1956. 10 pp. Evaluation of data transmission over a teleprinting link to feed data from the test station to the computer.

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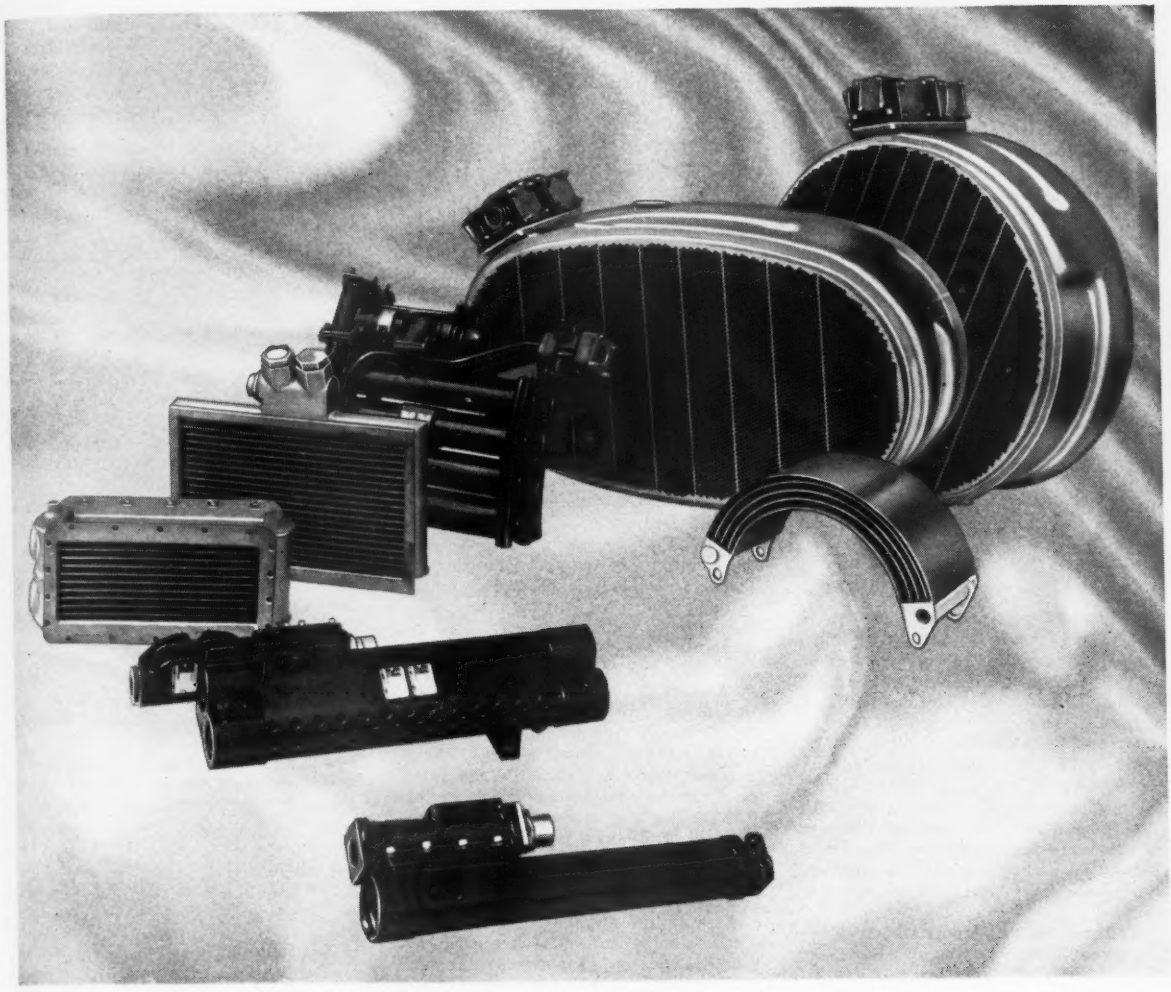

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based on the use of Laplace transforms. Includes numerical results obtained with the aid of a digital computer for various values of the surface resistivity of the strip.

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Radiation from a Vertical Antenna Over a Curved Stratified Ground. James R. Wait. *U.S., NBS J. Res.*, Apr., 1956, pp. 237–244. 13 refs. Analysis of propagation over a curved earth with concentric stratifications by extending Watson's method, in order to obtain a solution for the electric dipole radiating over a homogeneous sphere.

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Automatic Measurement of Phase Retardation for Radome Analysis. Melvin J. Kofoid. *Rev. Sci. Instr.*, July, 1956, pp. 450–452. Development of a microwave interferometer for measuring the phase retardation of a wave passing through a radome wall.

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Phase Angle Distortion in Traveling-Wave Tubes. W. R. Beam and D. J. Blattner. *RCA Rev.*, Mar., 1956, pp. 86–99. Derivation of expressions for variations in shift, using Pierce first-order theory, with experimental verification.

The Nature of Power Saturation in Traveling Wave Tubes. C. C. Cutler. *Bell System Tech. J.*, July, 1956, pp. 841–876. 29 refs. Study of the nonlinear operating characteristics of a traveling-wave tube, using a tube scaled to low frequency and large size. Measurements of electron beam velocity and current as a function of r.f. phase and amplitude are given to show the mechanism of power saturation.

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On the Distribution of the Product of Diode Detector Waveforms. E. L. R. Webb. *Can. J. Phys.*, July, 1956, pp. 679–691. Theoretical analysis over the

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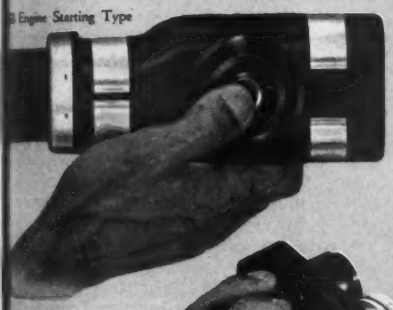

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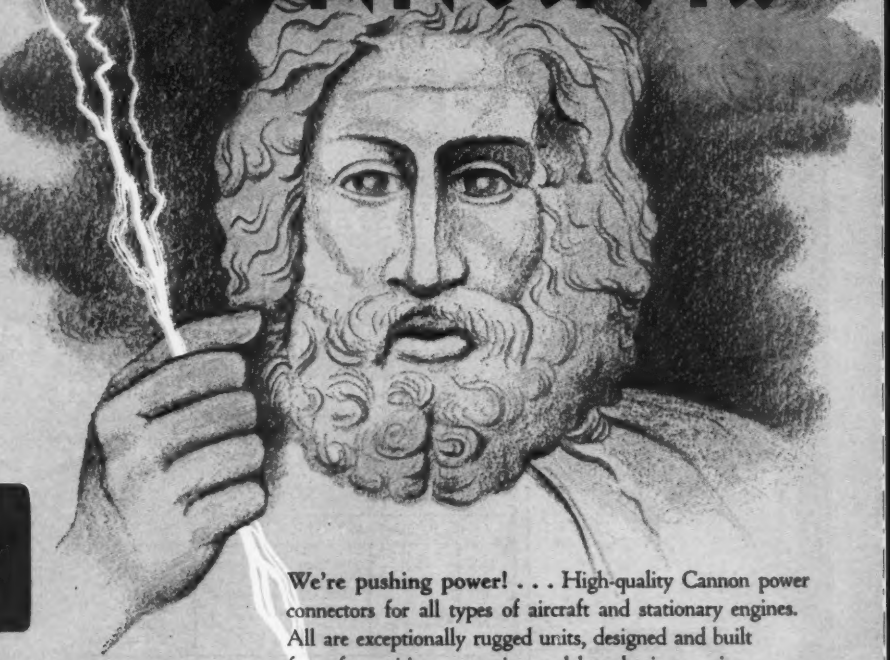

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11751-1 . . . for aircraft batteries, two 600 amp. contacts.

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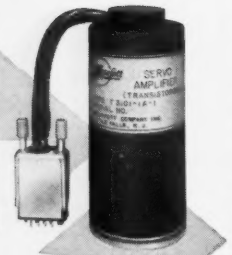
11	.63 oz. in.	6700 RPM	3.5	4.5 oz.
15	1.53 oz. in.	5300 PRM	6	7.30 oz.
18	2.4 oz. in.	5300 RPM	9	12.2 oz.



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whole range of the signal-to-noise ratio for the probability distribution of the product of two wave forms which come from the diode second detectors of radio receivers. Computed curves of probability density are given for small and moderate values of signal-to-noise ratio, and the limiting form for large signal-to-noise is indicated.

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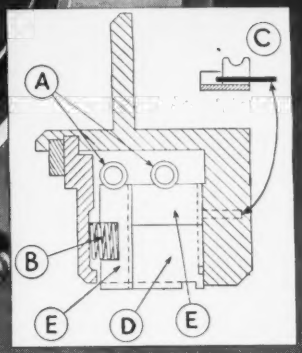

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optimum frequency stability, with an analysis of possible modification to eliminate the amplifier stage.

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The Timing of the Attempt on the World Airspeed Record at Ford on 10th

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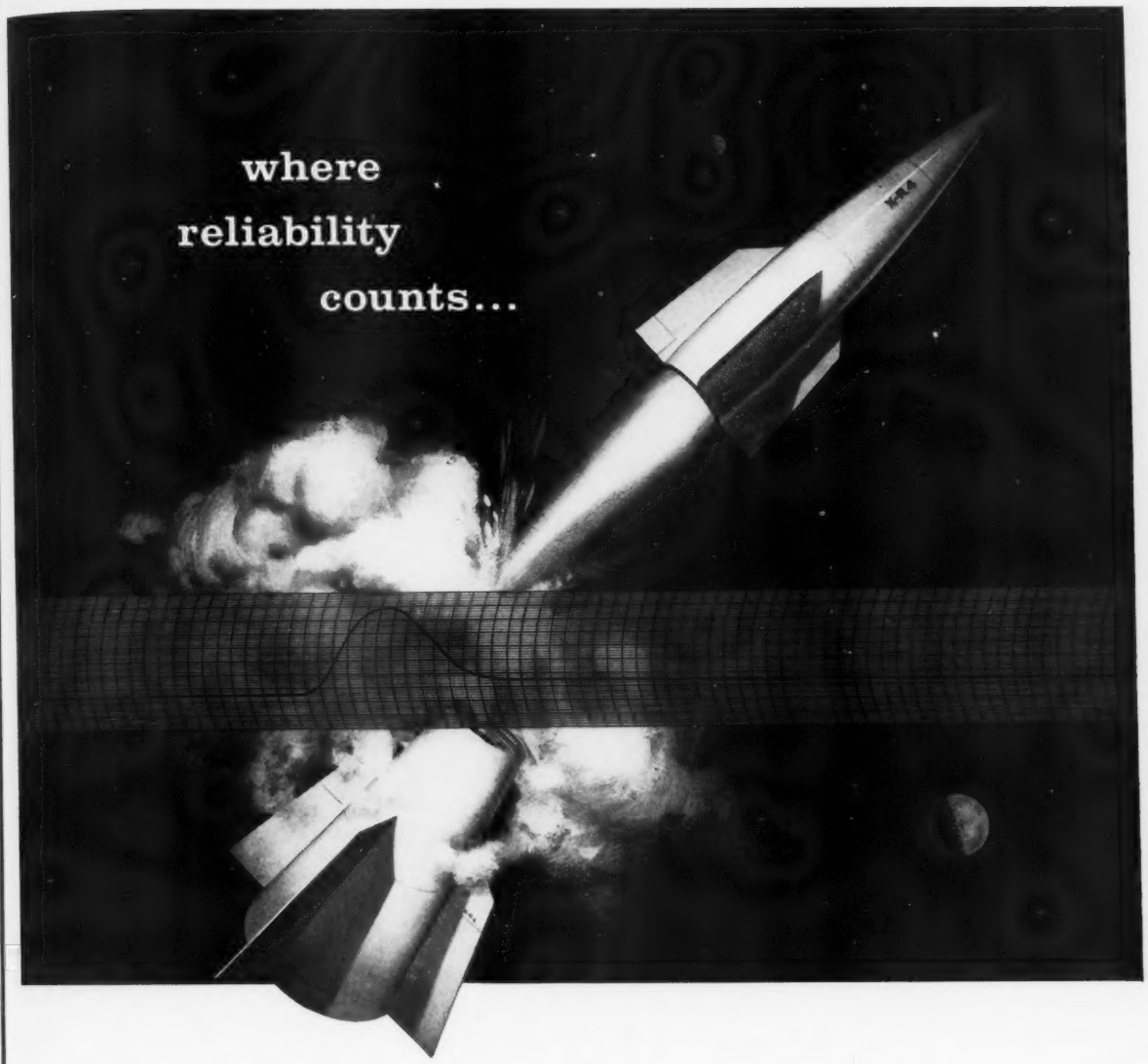

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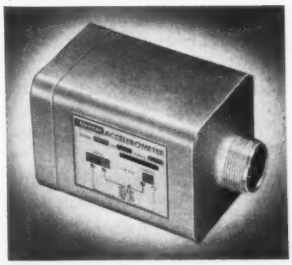

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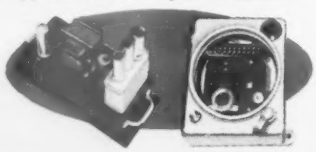

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and variables for using the pendulum are described.

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Indukcyjne Przekaźniki Nieograniczonych Kątów Obrotu i ich Zastosowanie w Automatyce Lotniczej. I. Janusz Morawski. *Tech. Lotnicza*, May-June, 1956, pp. 75–83. In Polish. Evaluation of induction transmitters of unlimited angular motion and their use in aviation automatics.

Criteria for Evaluating Servo System Performance. I, II. J. M. Nightingale. *Mach. Des.*, July-Aug., 1956, pp. 78–84, 106–110. Analysis of stability and response in servosystems, taking into account frequency response, and stability, Niquist, algebraic, and response criteria.

Fondamenti della Teoria dei Servomeccanismi. Lorenzo Poggi. *U. Pisa. Eng. Fac. Rep. 753*, 1955. 249 pp. In Italian. Analysis of fundamental aspects of the theory of servomechanisms.

Improved On-Off Stabilization Systems. Robert W. Bass. *Aero. Dig.*, Aug., 1956, pp. 28–32. 18 refs. Description of a new synthesis procedure which eliminates the delays arising from time-lag and hysteresis in the relay or contractor in on-off control systems. Applicable to missile control systems.

A Valve-Controlled Hydraulic Servomechanism. D. V. Stallard. *Elec. Eng.*, Aug., 1956, pp. 710. Abridged. Theoretical investigation of a complete hydraulic servo having an amplifier, a single-stage flow-control valve, a single-vane rotary motor with inertia load, and a position feedback.

The Dual-Input Describing Function and Its Use in the Analysis of Non-Linear Feedback Systems. J. C. West, J. L. Douce, and R. K. Livesley. (*IEE Paper 1877 M.*) *Proc. IEE, Part B*, July, 1956, pp. 463–474. 13 refs.

Lo Studio dei Servomeccanismi con il Metodo della Funzione a Gradino. Carlo Arneodo. (*Atti e Rass. Tec. Soc. Ing. e Arch. Torino*, Nov., 1954.) *Torino*

Polytech. Inst., Aero. Lab., Monograph 346, 1955. 9 pp. In Italian. Brief outline of a method for the solution of analog circuits.

I Circuiti Analogici Applicati allo Studio dei Servocomandi. Carlo Arneodo. (*Atti e Rass. Tec. Soc. Ing. e Arch. Torino,* Oct., 1954.) *Torino Polytech. Inst., Aero. Lab., Monograph 344,* 1955. 5 pp. In Italian. Application of analog circuits to the study of servomechanisms.

Design Basis for Multiloop Positional Servomechanisms. Sidney Lees. (*ASME Diamond Jubilee Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME,* Aug., 1956, pp. 1,339–1,361. Description of a design method which takes interferences, uncertainties, and dynamic factors into account simultaneously, requires only the closed-chain performance equations, and distinguishes between system and component performance.

An On-Off Servo Mechanism with Predicted Change-Over. J. F. Coales and A. R. M. Noton. (*IEE Paper 1895 M.*) *Proc. IEE, Part B,* July, 1956, pp. 449–462. 15 refs. Results of theoretical investigation indicating that one change-over, at a unique time, is necessary to bring error and error rate to zero in the least possible time for a relay-controlled servomechanism represented by an *n*th-order differential equation.

Flight Instruments

Error in Airspeed Measurement Due to the Static-Pressure Field Ahead of an Airplane at Transonic Speeds. Thomas C. O'Bryan, Edward C. B. Danforth, and J. Ford Johnston. *U.S., NACA Rep. 1239,* 1955. 13 pp. 14 refs. Supt. of Doc., Wash. $0.20. Theoretical and experimental determination of the magnitude and variation of the static-pressure error for various distances ahead of sharp-nosed bodies and open-nosed air inlets and for a distance of one chord ahead of the tip of a swept wing. Includes detailed discussion of the mechanism of error to show the contributing factors. Results are applicable to the selection of proper location for static-pressure measurements.

Tafeln und Tabellen zur Ermittlung der Eigengeschwindigkeit eines Flugzeuges und der Machzahl im Unterschallbereich. E. Nickel. *DFL Braunschweig, Inst. Luftfahrzeugf. Bericht L 42–54/5,* Dec. 30, 1954. 26 pp. In German. Charts and tables for the determination of true air speed of an aircraft and of the Mach Number in the subsonic range from air temperature and dynamic and static pressure parameters.

Über die Ermittlung der Eigengeschwindigkeit eines Flugzeuges mit einem Rechenschieber im Unterschallbereich. O. Weber. *DFL Braunschweig, Inst. Luftfahrzeugf., Bericht L 44–55/7,* Mar. 15, 1955. 39 pp. 12 refs. In German. Analysis of the determination of the true air speed of an aircraft in the subsonic region and of an approximation obtained from several speed and altitude indicators and thermometer-type instruments, using a slide rule. The influence of air compressibility and the friction-generated heating of temperature-measuring devices is taken into account.

Fahrtmesser und Machmeter. H. Sarnow. *DFL Braunschweig, Inst. Luftfahrzeugf., Bericht 45–55/8,* June 5, 1955. 27 pp. In German. Measurement of the natural velocity of an aircraft based on the calculation of the impact pressure, taking into account different correction values and the measured Mach Number. Includes description of a Kollsman-type speed indicator.

Flow Measuring Devices

Mesure des Valeurs Efficaces des Composantes de la Turbulence en Soufflerie par un Voltmètre Intégrateur. J. Fiquet. *La Recherche Aéronautique,* May-June, 1956, pp. 31, 32. In French. Description of an integrating voltmeter used in a series of measurements for studying the turbulence in the Modane sonic facility. It permits the measurement of effective values of uncertain electrical signals of given origin.

The Hot-Film Anemometer: A New Device for Fluid Mechanics Research. S. C. Ling and P. G. Hubbard. *J. Aero. Sci.,* Sept., 1956, pp. 890, 891. Description of a new heat-transfer-type sensing element consisting of a very thin platinum film fused to a glass surface, developed for the study of flow characteristics in both gases and liquids.

Strömungstechnische Aufgaben im Lichte der Messtechnik. R. Wille. *VDI-Zeitschrift,* May 11, 1956, pp. 756–760. 13 refs. In German. Description of a hot-wire anemometer and discussion of its application to flow measurements.

Timing Devices

Time Correlator for Problems in Aerodynamics. George Tolmie Skinner. *U.S., NACA TN 3682,* June, 1956. 32 pp. Description of an instrument storing periodic samples of the signal in a box from which they are recovered after a predetermined delay time. The device makes use of the general statistical properties of the signals to be handled.

Timing Marker Generator. Loren E. Bollinger. *Instruments & Automation,* July, 1956, pp. 1,329–1,330. Abridged. Description of a 1-sec. timing signal generator used in evaluation tests of rocket-engine propellants.

Improved Equipment for Timing World Airspeed Records at High Altitude. N. E. G. Hill and W. Goldsmith. *Gt. Brit. RAE Rep. Instn. 6,* Apr., 1956. 35 pp. Development of timing equipment for use under F.A.I. rules. A camera and chronometer were especially designed and are described.

Machine Elements

K Teorii Sfericheskogo Podshipnika. L. G. Loitsianskii. *Pikl. Mat. i Mekh.,* 1956, pp. 133–135. In Russian. Derivation of a solution for the problem of motion of an incompressible viscous liquid between two spherical surfaces.

Materials

Tensile and Tensile Fatigue Properties of Transparent Enclosure Attachments for Aircraft. Edward Holm, William Yamaguchi, M. Elber Latham, and J. G. Stansbury. *USAF WADC TR 54–396,* July, 1954. 71 pp.

Corrosion & Protective Coatings

The Oxidation of Aluminium in Dry and Humid Oxygen Atmospheres. R. K. Hart. *Proc. Royal Soc. (London), Ser. A,* July 10, 1956, pp. 68–88. 55 refs. Investigation on polished aluminum single-crystal surfaces in dry oxygen at 20°C. and one atmosphere and in 80 per cent saturated oxygen at 25°C. and one atmosphere. Three methods are used to identify and estimate the film surfaces: anodic polarization, electron diffraction, and capacitance measurement.

Anodized Coatings for Aluminum. R. V. Vanden Berg. *Materials & Methods,* July, 1956, pp. 90–94. Discussion of the anodizing process, taking into account electrolytes, coloring, the effects of alloying elements and of anodizing on material parts, and the forming characteristics.

Ein Beitrag zum Problem der Spannungskorrosion bei Pressprofilen und Pressteilen aus Aluminium-Legierungen. W. Rosenkranz. *Nordrhein-Westfalen, Wirtsch. & Verkehrsmin., Forschungsbericht No. 158,* 1956. 98 pp. DM 27.40. In German. Study of the problem of stress corrosion in aluminum-alloy molded and extruded specimens, with an analysis of the discrepancy between theory and experiment.

Metals & Alloys

A Dictionary of Metallurgy. XLV—*Sp–St.* A. D. Merriman and J. S. Bowden. *Metal Treatment,* July, 1956, pp. 273–280.

Aircraft Armament Equipment. R. E. Kemelhor. *Aero. Eng. Rev.,* Sept. 1956, pp. 48–53. Discussion of the metallurgical and material problems involved in the design, development, and manufacture of aircraft armament, with emphasis on the need for a high-strength, corrosion-resistant stainless-steel material for use in bombing systems. Includes data on other materials used in aircraft armament mechanisms.

Poisson's Ratios and Volume Changes for Plastically Orthotropic Material. Elbridge Z. Stowell and Richard A. Pride. *U.S., NACA TN 3736,* Aug., 1956. 28 pp. Measurements of Poisson's ratios in three orthogonal directions on aluminum-alloy blocks in compression and on stainless-steel sheet in both tension and compression, resulting in a method to correlate the measured individual values of the Poisson ratios and the stress-strain curves for the material.

Fatigue Strength of Alloy Steel Bars with a Round-Crack. Tadasi Isibasi and Tsunemi Uryu. *Kyushu U., Japan. Rep. Res. Inst. Appl. Mech.,* Jan., 1956, pp. 57–65. Results of tests for the determination of fatigue strength of round-cracked specimen of nickel-chromium and chromium-molybdenum steels subjected to rotary bending stress.

Investigation of Ball Race Steels. *Gt. Brit., MOS S&T Memo. 17/55,* Jan. 19, 1955. 8 pp. Results of hardness and fatigue tests on heat-treated steels used for ball bearings.

Creep and Design. Ward F. Simmons. *Battelle Tech. Rev.,* July, 1956, pp. 10–14. Discussion of creep problems and creep-rupture studies, with particular emphasis

(*Continued on page 148*)

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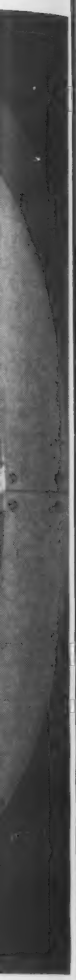

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ACOUSTICS, SOUND, & NOISE

ACOUSTIC RADIATION FROM A STATIONARY CYLINDER IN A FLUID STREAM (AEOLIAN TONES). B. Etkin, G. K. Korbacher, and R. T. Keefe. UTIA Rep. 39, May, 1956. 45 pp. 20 refs. Application of Lighthill's equations for the sound due to body forces to the flow past a circular cylinder, in order to make quantitative predictions of the directionality and intensity of the sound field and of the total power output. Includes subsonic wind-tunnel tests for providing qualitative experimental verification of theoretical results, which indicate that the sound field is related to the oscillating lift and drag forces acting on the cylinder. Measurements are taken of the overall sound pressure levels and sound spectra with various cylinders mounted in the test section by using microphones located both inside and outside the tunnel.

AERODYNAMICS

Aerothermodynamics

NOTE ON THE FLOW FIELDS ON THE REAR PART OF BLUNT BODIES IN HYPERSONIC FLOW Antonio Ferri and Adrian Pallone. USAF WADC TN 56-294, July, 1956. 19 pp. Discussion emphasizing the importance of entropy effects as a function of Mach Number and indicating how these effects increase with Mach Number to achieve considerable significance in the M=10 to M=20 range. Theoretical consideration is given to the effects of entropy rise and Mach Number variations on pressure and heat-transfer distributions at the shoulder of wedge-plate or cone-cylinder configurations, and to pressure distribution in the rear part of a closed body or at the base of a blunt body. Analysis assumes a perfect gas and neglects dissociation of gas molecules.

AN INVERSE PROBLEM IN HYPERSONIC VISCOUS FLOW. T. Y. Li. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5603 (AFOSR TN 56-308), July 13, 1956. 35 pp. Analysis to determine a body shape from a prescribed pressure field. A tangent-wedge approximation is used to provide an explicit relation for the pressure inside the boundary layer and the local effective body inclination. The moment integral method is used in the analysis of the boundary layer growth. For the prescribed pressure field an iterative scheme is deviced to compute the necessary body shape. Numerical examples are computed for a specific pressure field at M = 10 for a range of Reynolds Numbers in three different cases: (1) a heated surface, (2) a cooled surface, and (3) a super-cooled surface. Results show that the iterative scheme converges rapidly and provides an example which exhibits continuous transition from the strong interaction solution to the weak interaction solution.

ETUDE EXPERIMENTALE DE LA CONVECTION FORCÉE SUR PAROI MOBILE (HYPERCONVECTION FAVRE). Charles Bory. France, Min. de l'Air PST 312, 1956. 70 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Fr. 1,000. In French. Study of the heat transfer between the flow of air and a cylinder, whose wall is partially exposed to the wind. Measurement of the convection coefficient for several wind velocities; for each of them a determination is achieved for the motionless wall and for different velocities of the wall, obtained by rotating the cylinder about its own axis. The most interesting phenomena correspond to the experiences where the wind velocity and the velocity of the wall follow the same direction (Favre hyperconvection). Lagrangian variables are used for determining a numerical procedure for the calculation of aerodynamic and thermal phenomena within the boundary layer, applicable to general cases.

AEROTHERMODYNAMIQUE FONDAMENTALE ET NOTIONS D'AÉROTHERMOCHIMIE. Maurice Roy. France, ONERA Pub. 84, 1956. 68 pp. In French. Evaluation of fundamental aerothermodynamics and of principles of aerothermochemistry leading to the derivation of the mechanics of continu-

ous and deformable media. The concept of efficiency is discussed for several applications and the isentropic efficiency of the rate of fluid flow is analyzed. One-dimensional flows are studied, taking into account both the case of chemical reaction and that of thermal interaction within and at the boundary of the media. Also discussed are phenomena occurring during the "thermal blocking" or "aerothermochemical blocking", conditions of maximum output of a heated or cooled cylindrical nozzle, and influence of the energy dissipation.

INTEGRAL METHODS FOR LAMINAR HEAT-TRANSFER CALCULATIONS. J. A. F. Hill. MIT NSL TR 159, June 1, 1955. 54 pp. 29 refs. Evaluation of known methods, classified in types according to the assumptions on which they are based, with the results of the evaluation leading to suggestions for reforms. The fundamental aspects of the integral approach are examined from Thwaites' point of view which emphasizes the conclusions which can be drown from the exact solutions, and the consequences of each assumption on which the various methods are based are thus compared with an exact solution for the heat-transfer-rate distribution on an isothermal cylinder in low-speed, constant-properties flow. It is shown that the best results can be obtained by fixing the shape of the temperature profile and allowing the thickness of the thermal boundary layer to be determined by the integral energy equation.

LAMINARNYI POGRANICHNYI SLOI SZHIMAEMOGO GAZA NA PLASTINE PRI BOL'SHIKH PEREPADAKH TEMPERATUR. V. V. Lunev. Prikl. Mat. i Mekh., May-June, 1956, pp. 395-401. In Russian. Investigation of the laminar boundary layer over a flat plate, neglecting the simplifying assumptions of the temperature dependence of viscosity. The Prandtl Number is assumed to be constant or very little influenced by the temperature. The analyzed temperature ratio includes the region of flow separation. For constant boundary conditions, the method of successive approximations, leading to the exact solution of the problem, is given and formulated for a large ratio of boundary conditions.

MASS TRANSFER COOLING OF A LAMINAR AIR BOUNDARY LAYER BY INJECTION OF A LIGHT-WEIGHT GAS. E. R. G. Eckert, P. J. Schneider, and F. Koehler. U. Minn. Inst. Tech. Dept. Mech. Eng. TR 8 (OSR TN 56-136), Apr., 1956. 24 pp. Velocity, concentration, and temperature field calculations for a laminar boundary layer created by high-velocity, steady two-dimensional air flow with locally uniform pressure and with fluid (hydrogen) injection from the surface. All fluid properties are assumed to vary with local mixture concentration and temperature in the boundary layer. Results in the form of profiles of the parameters investigated are given for a particular free-stream air temperature of 392°F., a free-stream Mach Number of 12, a surface-to-free-stream temperature ratio of 6, and surface concentrations of 0, 0.2, 0.4, 0.8 and 0.9. The injection rate and skin friction are presented as a function of the surface concentration. Hydrogen is used because of the difference between its properties and those of air.

ON HEAT TRANSFER IN LAMINAR BOUNDARY LAYERS AT HIGH PRANDTL NUMBER. G. W. Morgan and W. H. Warner. J. Aero. Sci., Oct., 1956, pp. 937-948. 25 refs. ONR-sponsored analysis of the asymptotic behavior of the heat transfer in laminar boundary layers. The study is based on the assumption that, for a large Prandtl Number, the conduction term in the energy equation must be important only in a region that is very narrow compared with the velocity boundary layer, but both convection and conduction are essential in that region. A transformation based on the Prandtl Number of the coordinate normal to the body surface leads to a form of the energy equation in which the appropriate convection and conduction terms can be balanced with respect to their asymptotic dependence on the Prandtl Number, and the behavior of the local heat-transfer coefficient can be deduced immediately.

THE EFFECT OF HEATING AND COOLING ON THE STABILITY OF THE BOUNDARY-LAYER FLOW OF A LIQUID OVER A CURVED SURFACE. R. C. Di Prima and D. W. Dunn. J. Aero. Sci., Oct., 1956, pp. 913-916. 12 refs. Investigation of the effects of heat transfer on three-dimensional instability of laminar boundary layers over concave surfaces. Results of numerical calculations for boundary-layer flow of water indicate that heating and cooling of the wall have only a small influence on this type of instability, as compared to their effect on the usual two-dimensional instability. For three-dimensional instability the centrifugal force is the controlling factor, and depends only on the overall properties of the basic-flow distributions, such as the average velocity gradient.

APPLICATION OF HYDRAULIC ANALOG METHOD TO ONE-DIMENSIONAL TRANSIENT HEAT FLOW. E. L. Knuth and E. L. Kumm. Jet Propulsion, Aug., 1956, pp. 649-654, 659. Extension of the analogy between one-dimensional transient heat flow and flow of a liquid through a tube to include certain boundary conditions which occur in problems involving aerodynamic heating. The design and construction of a hydraulic analog computer are described. Results indicate that nonlinear variations of environmental temperature and heat transfer coefficient with time, and nonlinear variations of thermal properties of a wall material with temperature can be handled easily; and that a clear physical picture of the temperature variations in the wall is obtained by observing the computer during its operation.

THE BOLTZMANN H-FUNCTION APPLIED TO THE SHOCK TRANSITION. Appendix A - DISTRIBUTION FUNCTION AND INTEGRATION FORMULAE. Appendix B - APPROXIMATIONS TO BOLTZMANN'S H-FUNCTION. Appendix C - MATHEMATICAL SOLUTION OF THE SHOCK TRANSITION.

E. L. Harris and G. N. Patterson. UTIA Rep. 40, May, 1956. 32 pp. USAF-supported study including calculation of the Boltzmann H-function for a Maxwell distribution function and for two nonisentropic cases. The variation of H through a shock front is given for Mach Numbers 1.5 to 4.0. Results indicate that viscosity and heat conduction have a marked effect on the transition of the Boltzmann H-function through a shock wave, tending to reduce the thermodynamic entropy function when plotted between two equilibrium states.

Boundary Layer

RAPID LAMINAR BOUNDARY-LAYER CALCULATIONS BY PIECEWISE APPLICATION OF SIMILAR SOLUTIONS. A. M. O. Smith. J. Aero. Sci., Oct., 1956, pp. 901-912. 15 refs. Method for the rapid calculation of the incompressible laminar boundary layer in an arbitrary flow around either a two-dimensional or a rotationally-symmetrical body. Solution is obtained by means of a coarse step-by-step procedure in which each segment of the velocity distribution is approximated by one of the Falkner-Skan family of similar flows. Solutions have at least as much accuracy as any other one-parameter approximate method. In regions of accelerating flow the accuracy appears to be very high, while in decelerating flows the separation is predicted somewhat early as compared with exact solutions.

PRIBLIZHENNOE RESHENIE NEKOTORIKH NESTATSIONARNYKH ZADACH POGRANICHNOGO SLOIA. E. M. Dobryshman. Prikl. Mat. i Mekh., May-June, 1956, pp. 402-410. In Russian. Derivation of an approximate solution for certain nonstationary problems of the boundary-layer theory. The Shvets technique is applied to the method of "layer of finite thickness" in calculating the stationary problems, and the Targ procedure for nonstationary cases is analyzed.

NÄHERUNGSTHEORIE FÜR KOMPRESSIBLE TURBULENTE GRENZSCHICHTEN. A. Walz. (GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM, Sonderheft, Aug., 1956, pp. 50-56. In German. Development of an approximation theory for compressible, turbulent boundary layers. Includes determination of the change occurring in the conventional representation of the wall shearing stress and dissipation owing to the influence of the change in material value, which, in the case of thermally insulated wall, is expressed as a function of the Mach Number of the outside flow M; and of the Mach Number reached under the assumption of relatively low speed of the exchange process.

Control Surfaces

RECHERCHES THÉORIQUES ET EXPÉRIMENTALES SUR LE CONTRÔLE DE CIRCULATION PAR SOUFFLAGE APPLIQUÉ AUX AILES D'AVIONS. L. Malavard and P. Jousserandot. France, ONERA NT 37, 1956. 75 pp. 12 refs. In French. Evaluation of the problem of reducing the speed and the take-off and landing distance of modern aircraft by a combination of external and internal aerodynamics. The emphasis is on theoretical and experimental means of controlling the circulation around airfoil profiles by accordingly orienting a jet blast at the trailing edge.

A FURTHER DISCUSSION ON MIXING AND THE JET FLAP. B. S. Stratford. Aero. Quart., Aug., 1956, pp. 169-183. Analysis of jet mixing by using momentum principles and a quantitative examination of the sink effect. Results show that in mixing between the main stream and the jet, one aspect, the primary change in thrust, is understood and can be calculated. This aspect may be associated with the change in magnitude of the jet and the main stream velocities due to the fact that the static pressure in the mixing region is different from that at infinity. The secondary loss is not so well understood and cannot yet be calculated. This loss is due to the entrained fluid travelling locally in a different direction from that of the jet with which it is mixing. Under cruising conditions the mixing of the jet with the boundary layer seems likely to influence both the optimum shape of the wing profile and its performance characteristics. This factor suggests that the optimum lift coefficient and also the minimum lift/drag ratio could be appreciably increased.

Fluid Mechanics & Aerodynamic Theory

EIN VERFAHREN ZUR UNTERSUCHUNG DES AUSTAUSCHVORGANGES IN VERWIRBELTEN STRÖMUNGEN HINTER KÖRPERN MIT ABGELÖSTER STRÖMUNG. August-Wilhelm Quick. Nordrhein-Westfalen, Arbeitsgemeinschaft für Forschung, Heft 50, 1956, pp. 35-67; Discussion, pp. 69-78. In German. Development of a method for studying the mixing process in vortices behind blunt bodies with separated flow. Theoretical determination of the process shows that, by measuring the concentration of the noise introduced into the vortex street, it is possible to determine the mass of air exchanged between the external flow and the vortex. In conjunction with this result and with the measurement of the velocity distribution in the vortex street, such values as the damping factor, the duration of the intake-value presence within the vortex, its revolving time and value, as well as the exchange factor are given. It is also shown that the exchange value can be determined approximately from the resistance of a body.

OB ASIMPTOTICHESKIKH RESHENIIAKH URAVNENII ODNOMERNOGO NEUSTANOVIVSHEGOSIA DVIZHENIIA IDEAL'NAGO GAZA I OB ASIMPTOTICHESKIKH ZAKONAKH ZATUKHANIIA UDARNYKH VOLN. Iu. L. Iakimov. Prikl. Mat. i Mekh., Nov.-Dec., 1955, pp. 681-692. In Russian. Investigation of three types of asymptotic solutions for linear equations of unsteady motion of an ideal gas having spherical symmetry, taking into account Landau, Zel'dovich, and Sedov results. The calculation is performed by using functional series. The

first two solutions contain one given function and sets of given numerical constants. A numerical example of applying the obtained results with arbitrary functions to the problem of asymptotic behavior of shock waves is discussed. This problem is divided into two sections, (a) study of the speed with which the intensity of the shock wave recedes and (b) methods of measuring the shape of the shock wave.

MEHRPARAMETRIGE ZÄHIGKEIT ALS GRUNDLAGE EINER QUASI-KONTINUUMTHEORIE DER COMPRESSIONSFRONT FÜR MEHRATOMIGE GASE. J. Theodorides. (GAMM, Fachausschuss für Strömungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM, Sonderheft, Aug., 1956, pp. 38-46. 44 refs. In German. OSR-sponsored investigation of multiparametric viscosity as basis for a quasi-continuum theory of compression fronts in polyatomic gases. Study includes: symmetry of the stress tensor; three independent viscosity mass parameters, one for the linear volume viscosity, and one for each linear and nonlinear shear viscosity. Through a superposition of transposed matrices, the tensors of the speed of deformation and the total stress are symmetrized; the dynamic equations presented in three-dimensional form; the laws for obtaining mass, impulse, and energy are confined to the uniaxial, constant case, with the equation of state combined and transformed. The integration for the case of temperature-dependent characteristics is discussed.

OBTEKANIE TONKIKH TEL V TREKHMERNOM POTOKE. M. D. Khaskind. Prikl. Mat. i Mekh., Mar.-Apr., 1956, pp. 203-210. In Russian. Application of the method of potential theory to the study of three-dimensional flow around thin bodies, leading to the formulation of an equation for the curved lifting line, including the determination of the occuring limitations. The equations for the curved lifting line of semi-circular shape are solved for small and large Froude Numbers, and the approximate solution, taking into account the Froude Number for a vertical straight lifting line completely immersed in a heavy liquid, is derived.

UTOCHNENIE TEORII PROSTOGO KRAEVOGO EFFEKTA. A. L. Goldenweiser. Prikl. Mat. i Mekh., May-June, 1956, pp. 335-348. In Russian. Derivation of a more exact representation of the approximate theory for simple boundary effects, developed by Staerman and Heckeler for axi-symmetrical rotating profiles and applied by Rabotnov and Goldenweiser to arbitrarily shaped profiles. The study includes an analysis of the first approximation theory and a tentative development of more adequate methods.

OBTEKANIE PROFILEI POTOKOM DOZVUKHOVOI SKOROSTI SO SVERKHZVUKOVOI ZONOI, OKANCHIVAIUSHCHEISIA PRIAMYM SKACHKOM UPLOTNENIIA. F. I. Frankl'. Prikl. Mat. i Mekh., Mar.-Apr., 1956, pp. 196-202. 10 refs. In Russian. Investigation of the subsonic flow with a supersonic zone around profiles, resulting in a sudden rise of condensation. The Buseman experimental results are taken into account. The formulation of the problem is based on results obtained for flow of an incompressible fluid around circular cylinders, using the hodograph method.

EXPERIMENTS ON CIRCULAR CONES AT YAW IN SUPERSONIC FLOW. Maurice Holt and John Blackie. J. Aero. Sci., Oct., 1956, pp. 931-936. Investigation on two circular cones, one with a semiapex angle of 15° and the other with an angle of 20°. Pressure measurements are given for angles of yaw up to 25° and for a Mach Number of 3.53. The measured pressure distribution and also the lift and drag coefficients are compared with corresponding values calculated by theoretical methods. The three theoretical calculations are made using Stone's original method, the same method corrected for entropy, and the second order development of Stone's method by Kopal. Comparison shows that the Stone second-order theory gives the best agreement, and that the entropy correction alone is not sufficient to bring the first-order solution to agreement with experiment.

ATTENUATION IN A SHOCK TUBE DUE TO UNSTEADY-BOUNDARY-LAYER ACTION. Harold Mirels. US, NACA TN 3278, Aug., 1956. 60 pp. Description of a method for determining the attenuation of a shock wave in the tube, under the assumptions that the boundary layer is thin compared to the tube diameter and that it induces one-dimensional longitudinal pressure waves whose strength is proportional to the vertical velocity at the edge of the boundary layer. Results show the contributions of various regions in a shock tube to shock attenuation.

EFFECTS OF KINEMATIC VISCOSITY AND WAVE SPEED ON SHOCK WAVE ATTENUATION. Appendix I - REVIEW OF EMPIRICAL RELATIONS. Appendix II - DERIVATION OF THE ATTENUATION FUNCTION AND THE π COEFFICIENT. Appendix III - NOTE ON THE USE OF CONSTANT p_1 IN THE CONSTANT ν_1 EXPERIMENTS. Appendix IV - NOTE ON THE APPLICATION OF NON-STATIONARY, LAMINAR SKIN FRICTION COEFFICIENTS. D. W. Boyer. UTIA TN 8, May, 1956. 76 pp. 19 refs. Experimental investigation using schlieren records of the (x, t)-plane for the range of initial conditions and channel lengths to determine shock speeds, with viscosity and wave speed varied independently. Results give good agreement with the Trimpi-Cohen attenuation theory, and theoretical attenuation curves are plotted for both laminar and turbulent friction laws. Includes detailed results of other attenuation studies. It is shown that experimental results for all tubes follow a turbulent analysis for both low and high shock strengths and various initial conditions after very short distances of travel.

Internal Flow

ON A CLASS OF LAMINAR VISCOUS FLOWS WITHIN ONE OR TWO BOUNDING CONES. A. J. A. Morgan. Aero. Quart., Aug., 1956, pp. 225-

239. 10 refs. Analysis of a class of incompressible laminar viscous flows in which the component velocities are inversely proportional to the distance from the origin, and which provide exact invariant solutions of the Navier-Stokes equations. These solutions imply that when the flow is bounded by impermeable conical surfaces, it must be identically quiescent. If the bounding cones are not impermeable, closed solutions for the single-cone case are found in terms of elementary functions. A numerical example of such a flow with the fluid injected normal to the conical boundary is given. Such a simplification of the hypergeometric functions entering into the problem, however, cannot be achieved in the two-cone case.

RESHENIE OBRATNOI ZADACHI PLOSKOGO KAVITATSIONNOGO OBTEKANIIA KRIVOLINEINOI DUGI. G. N. Pykhteev. Prikl. Mat. i Mekh., May-June, 1956, pp. 373-381. 17 refs. In Russian. Analysis of the Gilbarg-Efros scheme representing a model cavitation flow with returning stream entering the cavity. The inverted problem of calculating the profile shape according to the given velocity distribution is also analyzed. Such problems are encountered in the projection of rational shapes of turbine blades and pumps with high cavitational capacity.

ANALYSIS OF LAMINAR INCOMPRESSIBLE FLOW IN SEMIPOROUS CHANNELS. P. L. Donoughe. US, NACA TN 3759, Aug., 1956. 25 pp. Derivation of perturbation solutions of pertinent equations, with results compared to those obtained from a fully porous channel. The perturbation parameter measures the amount of suction or injection (blowing) at the porous wall. Results: blowing decreases the friction parameter at the porous wall by 25% and suction increases the wall friction parameter by 50% in the semiporous channel with a given value of the perturbation parameter; pressure in the longitudinal direction decreases for zero and blowing (negative) values of the perturbation parameter for both semiporous and fully porous channels; sufficiently high suction values produce a pressure rise in the fully porous channel; either suction or blowing has more influence on the local dimensionless velocity profiles and on the wall-friction parameter for the semiporous than for the fully porous channel.

ON THE EFFECTS OF THE REYNOLDS STRESS ON HYDRODYNAMIC STABILITY. J. T. Stuart. (GAMM, Fachausschuss für Stromungsforschung, Tagung, Göttingen, Oct. 7, 1955.) ZAMM, Sonderheft, Aug., 1956, pp. 32-38. Investigation of the theory of hydrodynamic instability for finite disturbances. Infinitesimal disturbances depend upon the energy transferred from the mean flow to the disturbance flow, and the consequent readjustment of the mean flow. Since this in turn affects the rate of energy transfer, the critical Reynolds Number depends upon the magnitude of the disturbance. Using the Navier-Stokes equations the critical Reynolds Number for a finite disturbance is calculated. Also a solution of Burger's model theory is used to illustrate the properties of amplified disturbances above the critical Reynolds Number of instability.

TRANSMISSION OF OSCILLATORY PRESSURES THROUGH INSTRUMENT PIPE LINES. Shin'ichiro Takeda. Hosei U. Tech. Coll. Rep. 1, May, 1956. 37 pp. Theoretical and experimental investigation of a compressible fluid in a pipe line. The analysis develops first a basic theory, considering the fluid as an incompressible tube. The theory of oscillatory flow is developed for a compressible fluid, and the velocity distribution, the increase of the frictional resistance and total resistance coefficient, including the inertia effects, are calculated. This corrected basic theory shows that the resonance frequencies coincide well with experiments, but results on the resonance amplitude are not satisfactory. Further research shows that the polytropic index of the closed chamber changes with the frequencies of the transmitted oscillatory pressures. Taking into account this effect, the decay theory for oscillating pressure through a pipe is formulated, and the agreement with experimental values of resonance amplitude is shown.

EINFLUSS DER OBERFLÄCHENSPANNUNG AUF DIE AUSBILDUNG VON FLÜSSIGKEITS-HOHLSTRAHLEN. G. A. Euteneuer. Forschung Gebiete Ing., Ausg. A, No. 4, 1956, pp. 109-122. In German. Study of the influence of surface tension on the development of hollow liquid jets indicating that the development of such jets, produced by means of annular spray nozzles, can be calculated under the assumption of frictionless flow. Jet borders are evaluated from the established theory for various values of surface tension and density of the liquid, of the initial jet velocity, and of the design data of the spray nozzle, and are found to be in good agreement with observed jet borders up to the point where the jet breaks up into droplets. At small velocities, the hollow jet, owing to the surface tension, may be deformed to such an extent that spraying does not occur and the hollow jet contracts into a solid jet. By an adequate combination of the many independent variables only four parameters remain as governing the problem: a dimensionless Weber group, the radius of the nozzle, and two flow angles which are determined by the design data of the spray nozzle.

Stability & Control

DIE BESTIMMUNG DER FLUGZEUGPOLAREN FUR ENTWURFSZWECKE. I - UNTERLAGEN. D. Fiecke. DVL Bericht No. 15, June, 1956. 242 pp. 352 refs. Westdeutscher Verlag, Köln & Opladen. In German. Compilation of diagrams used for the determination of polars for different flight attitudes - lift, dependent on drag and angle of attack for given rigid-winged aircraft in subsonic region, and variations in aircraft aerodynamic values produced by shape and velocity changes. It is also pointed out that the accuracy of these polars corresponds to requirements established during the preliminary planning stage.

Wings & Airfoils

ON TRANSONIC AIRFOIL THEORY. Gottfried Guderley. J. Aero. Sci., Oct., 1956, pp. 961-969. Theoretical investigation of the development of flow over an airfoil with respect to the reciprocal of the aspect ratio, taking into account the effect of the flow field at a distance from the profile on that close to the profile. This effect is considered in the form of a boundary condition, formulated by means of the transonic similarity law, which is imposed by the flow at a distance on the flow close to the airfoil. The latter is then treated similarly to plane flows with a free-stream Mach Number close to one. Results establish the main trend of the spatial influence.

A METHOD FOR OPTIMIZING TWO-DIMENSIONAL AIRFOILS. T. A. Cincotta. Princeton U. Dept. Aero. Eng. Rep. 355, May, 1956. 31 pp. Description of a procedure involving comparison of the viscous and nonviscous solution and application of boundary-layer control in such a way that the ideal nonviscous solution is approached. Includes a preliminary experimental investigation of the method on a model equipped with a double-slotted flap. Results indicate the uniqueness and feasibility of the method.

SOME RECENT DEVELOPMENTS IN THE AERODYNAMICS OF WINGS FOR HIGH SPEEDS. R. T. Jones. ZFW, Aug., 1956, pp. 257-262. 32 refs. Review of work in transonic and supersonic theory, which includes a proposed correction formula for the effect of compressibility in two-dimensional subsonic flow; the equivalence rule and area rule for transonic speeds; reciprocal relations in linearized wing theory; and some general results connected with the problem of minimum wave resistance. Also an example is presented showing indentation of the fuselage for obtaining favorable interference with the wing at supersonic speeds.

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE SUBSONIC-FLOW FIELDS BENEATH SWEPT AND UNSWEPT WINGS WITH TABLES OF VORTEX-INDUCED VELOCITIES. Appendix A---DETAILED THEORETICAL CONSIDERATIONS. Appendix B---DOWNWASH, SIDEWASH, AND BACKWASH FUNCTIONS DUE TO A UNIT HORSESHOE VORTEX. W. J. Alford, Jr. US, NACA TN 3738, Aug., 1956. 91 pp. 24 refs. Analysis based on potential-flow theory with results compared to those obtained experimentally for flow fields beneath swept and unswept wing-fuselage combinations. The potential-flow theory used considers both spanwise and chordwise distributions of vorticity as well as the wing-thickness effects. It is shown that significant chordwise flow gradients exist beneath both swept and unswept wings at zero lift and throughout the lift range. Calculated effects of compressibility indicate that significant increases of chordwise variation of flow angles and dynamic-pressure ratios should be expected in going from low to high subsonic speeds.

AUFTRIEBSLOSCHUNG UND AUFWINDLOSCHUNG, ZWEI DUALE METHODEN DER LINEARISIERTEN ÜBERSCHALLTRAGFLÄCHENTHEORIE; ANWENDUNG AUF DEN DOPPELDREIECKSFLÜGEL. Hermann Behrbohm. ZFW, Aug., 1956, pp. 263-268. In German. Development of an up-wash cancellation technique which is applied to the calculation of total lift and pitching moment for thin double delta wings in supersonic flow, with the position of the leading edge kink and sweep of the leading edge in front and aft of the kink as variable parameters. The method lends itself to the calculation of local resultant pressure distribution over such wings.

ÜBER DEN AUFTRIEB EINES RINGFLÜGELS BEI BESCHLEUNIGTEM ODER VERZÖGERTEM ÜBERSCHALLFLUG. Jürgen Zierep. ZFW, Aug., 1956, pp. 269-272. In German. Method of characteristics is given for estimating the lift of a body with a stabilizing annular ring at any instant of accelerated or decelerated flight. For constant speeds the method converges into that given by Haack. The effects of acceleration and deceleration on the lift and thus on the stabilising properties of the control surface are discussed.

SOME PRELIMINARY RESULTS FROM WIND TUNNEL MEASUREMENTS ON MODELS WITH ANNULAR WINGS AT SUPERSONIC SPEEDS. L.-E. Nordström. ZFW, Aug., 1956, pp. 272-276. Investigation performed at Mach Numbers 2 and 3 on annular wings, concentrically mounted on cone-cylindrical bodies of revolution. Results are presented from three-component measurements on wings with different chord to diameter ratios, and with varied position of the body nose in relation to the wing leading edge but with constant wing and body diameters. The lift distribution on a cylindrical body due to the interference from an annular wing at Mach Number 3 is also shown for incidences from 3 to 12°. Some schlieren pictures and photographs from paint tests for visualization of the boundary layer flow on the model are presented.

A STUDY OF OPTIMUM SPATIAL LIFT DISTRIBUTIONS AT SUPERSONIC SPEEDS. A. M. Rodríguez. Douglas Rep. SM-19292, Nov., 1955. 39 pp. Generalization of the previously obtained approach applied to the problems of spatial lift distribution and interference. Study of the optimal space distributions that are contained in volumes of revolution, in ellipsoidal volumes, and in Mach envelopes of inclined planar regions, and investigation by means of Hayes' method of the interference drag between source, volume element, side force, and lift distribution, lead to the derivation of four interference theorems and a fifth theorem, concerned with the lower bound for the wave drag of optimal distributions of lift, volume elements and side force, that is general enough to apply to all aircraft configurations.

NOTE ON THE FORCES THAT ACT NEAR THE CENTRE AND THE TIPS OF SWEPT WINGS. Appendix I---THE FLOW AT LARGE DISTANCES

FROM A SEMI-INFINITE YAWED WING. D. G. Hurley. Australia, ARL AN 150, Feb., 1956. 14 pp. Development of a simple exact method for calculating the force acting near the end of a semiinfinite yawed wing of symmetrical section at zero, with results applicable to the prediction of the drag forces acting near the centers and the thrust forces acting near the tips of swept wings of large aspect ratio. These results indicate that these forces depend only on the angle of sweep and the airfoil section near the mid-semispan, provided that both remain the same for a sufficient length of span about this position. Thus, for example, although changes in the shape of a swept wing near its center may reduce the magnitude of the drag force that acts at the center section, such changes will not reduce the total drag force near the center.

A THEORY OF SLENDER DELTA WINGS WITH LEADING EDGE SEPARATION. K. W. Mangler and J. H. B. Smith. Gt. Brit., RAE TN Aero. 2442, Apr., 1956. 21 pp. 14 refs. Development of a potential theory for the "core", a region of flow with high vorticity produced by the rolling-up of the vortex sheet which extends from the wing and is formed by the separation of flow at incidence, along the highly swept leading edge of a slender delta wing. The theory assumes a conical velocity and is further based on the assumptions of slender wing theory. The three-dimensional problem reduces to a two-dimensional one, and the shape of the entire vortex sheet and its strength are determined by the two conditions, the flow must be parallel to the vortex sheet, and the pressure continuous across it. From these conditions the shape and strength of the core are formed and a graphical method for finding the remainder of the solution is outlined. Analytical results indicate that for a given delta wing the shape and strength of the sheet are uniquely determined by the incidence, and that the only effective parameter is the product of the incidence and the tangent of the sweep angle. Analysis also includes discussion of some features of the three-dimensional and the corresponding two-dimensional flow patterns.

AEROELASTICITY

O KOLEBANII PLASTINKI, DVIZHUSHCHEISIA V GAZE. A. A. Movchan. Prikl. Mat. i Mekh., Mar.-Apr., 1956, pp. 211-222. In Russian. Investigation of oscillations of a plate of infinite width moving through a gas at supersonic speeds in the direction from the fixed edge toward the free edge. The pressure of the gas is taken into account and defined by an approximate formula. The relationship between the characteristics of the proper oscillations and the frequency of oscillation of the plate permits some conclusions to be drawn on the stability of motion. The formula of critical frequency is obtained.

OBRASHCHENIE TEOREM VTOROGO METODA LIAPUNOVA I VOPROSY USTOICHIVOSTI DVIZHENIIA PO PERVOMU PRIBLIZHENIIU. N. N. Krasovskii. Prikl. Mat. i Mekh., Mar.-Apr., 1956, pp. 255-265. 22 refs. In Russian. The theorems of the Liapunov second method and the problems of stability of motion are transformed according to the first approximation. The problems analyzed include: the relationship between the problems of the existence of Liapunov's function and of the concept of stability and instability proportions; the characteristics of a method for transforming the theorems of the Liapunov second method, applied to both stability and instability; proof of the existence of the Liapunov function satisfying certain conditions; and application of Liapunov's method of functions for studying stability according to the first approximation to the case where the trajectories of turbulent motion are considered in the abstract space.

AIRPLANE DESIGN

Landing Gear

THE THEORY AND PREVENTION OF UNDAMPED AEROPLANE NOSEWHEEL SHIMMY. D. Williams. Aero. Quart., Aug., 1956, pp. 193-220. Development of a mathematical theory of nosewheel shimmy, with particular emphasis on twin nosewheel assemblies. Experimental verification of the theory is outlined. Results show that the most important remedy for shimmy is to make the castor length greater than the creep distance, which in practice is found to be approximately equal to tire radius. Lateral flexibility of the oleo leg is disadvantageous but elastic constraint at the pivot is a good feature. The one necessitates an increased castor for stability while the other allows a smaller castor. By using a compact linkage mechanism, the effective castor length can be made independent of the wheel-leg offset and can have any desired value.

METHODE DE CALCUL DES AMORTISSEURS OLÉOPNEUMATIQUES ET COMPARAISON AVEC LES RÉSULTATS D'ESSAIS OBTENUS. E. Bazzocchi. Tech. et Sci. Aéronautiques, No. 3, 1956, pp. 125-139. In French. Development of a method for calculating oleo-pneumatic shock absorbers in aircraft landing gear. Includes an analysis of experimental results, taking into account the true dynamic characteristics of the regenerator and of the effects of friction. Results indicate that, in order to avoid speed vibrations of the absorber generated by the initial shock and due to the weight of wheels and other attached components (such as the piston of the shock absorber), and in order to obtain a diagram of the regular absorber and that with a constant maximum reaction for most of the run, the part of the run devoted to oil film has to vary with the run itself and has to be calculated exactly.

AVIATION MEDICINE

Human Engineering

THE ROLE OF VISUAL CUES IN FINAL APPROACH TO LANDING. II---A PROPOSED AIRBORNE APPROACH AID. III---PROPOSED RESEARCH PROGRAMME ON VISUAL CUES

AND APPROACH AIDS. Appendix I, II---MODIFIED NAVY ANGLE OF APPROACH INDICATOR. Appendix III---A TRAINING DEVICE FOR SIMULATING VISUAL LANDINGS OR VISUAL LANDINGS FOLLOWING INSTRUMENT APPROACHES. Appendix IV---FEASIBILITY OF CONSTRUCTING A UNIVERSAL AIRBORNE APPROACH SIGHT. J. C. Lane and R. W. Cumming. Australia, ARL Note HE. 1, May, 1956. 48 pp. 22 refs. Review of the information required by the pilot to select the point for initiating the final approach from straight-in and to establish and maintain the approach path, with a tabulation of the sources of information available to the pilot and recomendations for the development of training methods, including the use of a final approach simulator, to enable him to make optimum use of available cues. Ground and airborne visual aid devices are described and compared. A universal approach sight is described which would combine features of both the angle-of-depression sight and the aiming-point sight to give a simple display, including ILS information, for providing data on when to initiate the final approach and rate-display information to help the pilot hold a straight glide path throughout the approach.

ELECTRONICS

Cooling

FORCED-AIR TECHNIQUES FOR COOLING ELECTRONIC EQUIPMENT. Melvin Mark and Mark Stephenson. Elec. Mfg., Sept., 1956, pp. 130-136, 372 ff. 15 refs. Analysis of the cooling problem for airborne electronic equipment considering the vacuum tube as the basic heat generating source. Equations are derived for basic heat transfer by convection, radiation, and conduction for the general case. Two methods of cooling are presented, one by a forced-draft chimney and the other by a heat sink in the form of a forced-air-cooled cold plate. Design graphs are derived for several different parameters and compared with experimental data obtained for each type of cooling.

Dielectrics

A HOMOGENEOUS DIELECTRIC SPHERE AS A MICROWAVE LENS. G. Bekefi and G. W. Farnell. Can. J. Phys., Aug., 1956, pp. 790-803. 28 refs. USAF-supported computations applying geometric optics and the diffraction theory of optical aberrations to determine the feasibility of using a homogeneous dielectric sphere as a microwave lens. The investigation is based on the principle that such a sphere illuminated by a small external source of electromagnetic radiation is free, because of its special symmetry, from all off-axis aberrations such as coma and astigmatism, and that it can be used for rapid microwave-beam scanning through an angle of 360° of arc without moving the lens, provided that the spherical aberration is not too excessive or is partially corrected by a suitably designed source. The results suggest that a sphere of fairly small refractive index and less than 30 wave lengths in diameter will produce a good diffraction image of a point source. Includes discussion of methods of designing appropriate sources for use with larger spheres.

Telemetry

APPLICATION OF SEQUENCE TRANSFORM ANALYSIS TO THE DESIGN OF SAMPLING CONTROL SYSTEMS. A. R. Boothroyd and J. H. Westcott. Gt. Brit., RAE TN GW 405, Mar., 1956. 53 pp. Analysis of sampling control systems in which the input is in the form of discrete samples rather than continuous ones. The techniques described are applicable to guided weapon systems in which the guidance information is obtained intermittently. Control systems involving basically the double integrations of a clamped error signal are considered, and Barker's method of stabilizing the system in regard to its response sequence at the sampling times is applied. Methods of correcting oscillatory tendencies between sampling times are discussed, one possibility being to include a phase advance network in the forward path of the feedback loop. A double integrator control system with added phase advance is also analyzed.

FLIGHT TESTING

FLIGHT TECHNIQUES FOR DETERMINING AIRPLANE DRAG AT HIGH MACH NUMBERS. De E. Beeler, D. R. Bellman, and E. J. Saltzman. US, NACA TN 3821, Aug., 1956. 40 pp. 23 refs. Investigation of the stabilized-flight, energy, and accelerometer methods, with results indicating that the accelerometer technique is the most satisfactory in the determination of drag for research purposes, as it is the only one permitting a complete coverage of the Mach Number and angle-of-attack capabilities of an aircraft. It is also shown that this method requires the accurate measurement of longitudinal and normal accelerations, angles of attack, engine thrust, static pressure, airspeed, airplane weight, and longitudinal control positions, and ways of achieving such accurate data are described. Comparison of flight and wind-tunnel data must be made on the basis of component drags - consisting of trim, skin-friction, and pressure-induced and wave drags - for the proper interpretation of results.

FUELS & LUBRICANTS

PROPERTIES OF AIRCRAFT FUELS. H. C. Barnett and R. R. Hibbard. US, NACA TN 3276, Aug., 1956. 152 pp. 80 refs. Review and collection of available fuel data useful to the fuel-system designer which shows clearly the range of variation in fuel properties to be considered in fuel-system problems. The effects of external influences such as pressure and temperature on many of these properties are illustrated. Also an effort is made to indicate adequate measures by which some easily measured fuel properties may be used to predict other properties more difficult to determine by laboratory measurement. Data presented is re-

stricted to jet-engine fuels and several fuels of possible interest in the future.

OBSERVATIONS ON THE IRREGULAR REACTION OF SOLID PROPELLANT CHARGES. Leon Green, Jr. Jet Propulsion, Aug., 1956, pp. 655-659. 18 refs. Review of studies concerning reaction irregularities in solid-propellant rocket motors. Evidence is presented indicating that high frequency pressure oscillations of finite amplitude can prevail in the charge cavity during outwardly stable operation. A possible coupling mechanism by which gas phase oscillations may effect exaggerated rates of solid phase decomposition is suggested in qualitative terms.

INSTRUMENTS

A SATURABLE INDUCTOR MAGNETOMETER. A. Wilson. Gt. Brit., RAE TN TD6, Apr., 1956. 12 pp. Description of an instrument developed to measure the attitude of a missile relative to the earth's magnetic field. It is shown that, by using three sense elements mutually perpendicular to each other, it should be possible to measure the whole magnetic field, the accuracy obtainable depending on calibrations and on how accurately data can be telemetered to the ground.

CENTRALE DE MESURES AERODYNAMIQUES; VITESSES, NOMBRE DE MACH, TEMPERATURES. G. Dion. Tech. et Sci. Aéronautiques, No. 3, 1956, pp. 118-124. In French. Description of apparatus used (besides piloting or navigational purposes) for transmitting measured data for various recordings, automatic control, and target tracking. The device can be applied to servo-measurements including aerodynamic velocity, true speed, Mach Number, temperature, and altitude up to 90.000 ft., and is based on the generalized application of magnetic (pressure detection, magnetic amplification) or electromagnetic devices. The main device of the system is the true speed indicator, and the combined aerodynamic-speed and Mach Number indicator can be eliminated without distorting its proper functioning.

Flow Measuring Devices

THE BEHAVIOR OF TRANSVERSE CYLINDRICAL AND FORWARD FACING TOTAL PRESSURE PROBES IN TRANSVERSE TOTAL PRESSURE GRADIENTS. J. L. Livesey. J. Aero. Sci., Oct., 1956, pp. 949-955. Results of an investigation of the effect for certain transverse cylindrical and forward-facing (or pitot type) total pressure probes. An estimate of the error is given for transverse cylindrical type of probe, and the errors due to position and depth of the hole and wall proximity with this type of probe are considered. A design of a forward-facing type probe having negligible displacement error is suggested.

PROBE MEASUREMENTS IN THREE-DIMENSIONAL FLOW. F. A. L. Winternitz. Aircraft Eng., Aug., 1956, pp. 273-278. 20 refs. Survey of instruments and methods used to measure total and static pressure and direction, with comparative tests in a towing tank of two designs of five-orifice pitot-type probes with different head shapes. Speed and angle-of-flow characteristics are given for both probes. Results establish the advantage of the instrument with independent static-pressure orifices for measurements within a limited range of flow inclinations.

Temperature Measuring Devices

A SELF-BALANCING LINE-REVERSAL PYROMETER. Donald Buchele. US, NACA TN 3656, Aug., 1956. 68 pp. 12 refs. Description of an instrument for measuring gas temperatures from 2900° to 4500° R. The pyrometer incorporates as its two optical components a reflector and a fully enclosed unit containing a projection lamp, spectroscope, and photoelectric detector of line-reversal. It can be used to measure local temperature by the injection of a narrow stream of sodium-containing powder into the gas from a probe nozzle upstream of the point of measurement. Results of comparison with a thermocouple pyrometer and a pneumatic-tube instrument indicate that the average deviation of the line-reversal methods from the mean of all measurements is 60° R.

RESISTANCE THERMOMETER FOR HEAT TRANSFER MEASUREMENT IN A SHOCK TUBE. J. Rabinowicz, M. E. Jessey, and C. A. Bartsch. GALCIT Memo. 33, July 2, 1956. 33 pp. 10 refs. Development of a resistance thermometer for measuring surface temperatures and heat-transfer rates under highly transient conditions. By using a thin platinum film sputtered on the gage, a thermometer is obtained with a response lag of less than one microsec., a linear output of 2-3 mv/°C., repeatability, and durability. The gage preparation, including sputtering technique, calibration method, and response characteristics are discussed, and some measurements of surface temperatures and heat transfer rates on models in the shock tube are presented to illustrate the performance of the instrument.

MATERIALS

Metals & Alloys

INFLUENCE OF HOT-WORKING CONDITIONS ON HIGH-TEMPERATURE PROPERTIES OF A HEAT-RESISTANT ALLOY. Appendix - PROCESSING OF LOW-CARBON N-155 7/8-INCH BROKEN-CORNER SQUARE BAR STOCK FROM HEAT A-1726. J. F. Ewing and J. W. Freeman. US, NACA TN 3727, Aug., 1956. 134 pp. Experimental investigation with results serving to explain many of the observed variations in properties for the hot-worked condition. Includes tests conducted at constant temperature and with incremental decreases in temperature, and those using a few special cyclic conditions involving a small reduction at a high temperature followed by a small reduction at low temperature; rupture tests at 1,200° and 1,500°F.; and hardness, microstructures, and lattice-parameter measurements.

THE EFFECT OF VIBRATIONS ON THE MECHANICAL PROPERTIES OF H.R. CROWN MAX AND NIMONIC C.75. J. Jagaciak and J. W. Jones. Coll. of Aeronautics, Cranfield, Rep. 91, Sept., 1955. 42 pp. 15 refs. Experimental results demonstrate a marked improvement in the mechanical properties of castings due to the effect of vibrations in the subsonic range, confirmed by changes in the microstructure common to both materials. The maximum improvements occur at about 4,000 to 5,000 v.p.m. for H. R. Crown Max, and at about 75 to 85 v.p.s. for Nimonic C.75.

Metals & Alloys, Nonferrous

MECHANICAL TESTS ON SPECIMENS FROM LARGE ALUMINUM-ALLOY FORGINGS. J. A. Miller and A. L. Albert. US, NACA TN 3729, Aug., 1956. 25 pp. Results of tensile and bending tests in the T6 condition of 7075 and 2014 aluminum alloy. The stress and strain at failure varies with the location and direction of the specimen in the forging, but no consistent relation exists between the values for specimens parallel to the direction of the length of the forging and the values for specimens in either transverse direction. Biaxial tensile stress conditions resulting from induced transverse stresses combined with direct bending stresses, cause fracture to occur at a much lower strain than for bend specimens in which critical stresses are uniaxial.

TENSILE PROPERTIES OF HK31XA-H24 MAGNESIUM-ALLOY SHEET UNDER RAPID-HEATING CONDITIONS AND CONSTANT ELEVATED TEMPERATURES. T. W. Gibbs. US, NACA TN 3742, Aug., 1956. 20 pp. Results of rapid-heating tests on a magnesium alloy indicating that under constant load the yield and rupture temperatures vary approximately linearly with the logarithm of the nominal temperature rates from 0.2° to 100° F. per sec. At higher temperature rates of 60° to 100° F. per sec., the yield and rupture stresses are of the order of four to six times greater than the results of stress-strain tests at 600° F. Linear temperature-rate parameters are used to correlate rapid heating results by constructing master curves which can be used for predicting yield stresses and temperatures, and for estimating rupture stresses and temperatures.

TENSILE PROPERTIES OF AZ31A-0 MAGNESIUM-ALLOY SHEET UNDER RAPID-HEATING AND CONSTANT-TEMPERATURE CONDITIONS. I. M. Kurg. US, NACA TN 3752, Aug., 1956. 21 pp. Experimental investigation of specimens heated to rupture at nominal rates of 0.2°F. to 100°F. per sec. under constant tensile load conditions, with results compared to those of conventional tensile stress-strain tests at elevated temperatures after 1/2-hour exposure. A temperature-rate parameter is used to construct master curves from which stresses and temperatures for yield and rupture can be predicted under rapid-heating conditions, and a comparison of the elevated-temperature tensile properties of AZ31A-0 and HK31XA-H24 magnesium alloy sheet under both constant-temperature and rapid-heating conditions is included.

MATHEMATICS

SOME RATIONALITY QUESTIONS ON ALGEBRAIC GROUPS. M. A. Rosenlicht. Northwestern U. AFOSR TN 56-318, July, 1956. 43 pp. 10 refs. Extension, to include the case where k is an arbitrary perfect field, of Chevalley's proof that if G is a connected linear algebraic group defined over a field k, then the field k (G) of rational functions on G that are defined over k is k-isomorphic to a subfield of a purely transcendental extension of k when k is any field of characteristic zero. A number of other results on rationality questions is developed, including three propositions indicating that the study of the type of field extension obtained by adjoining the characteristic roots of a generic element of an algebraic group of matrices to the field of the generic element provides information on the structure of the group.

ON SUBHARMONIC FUNCTIONS AND DIFFERENTIAL GEOMETRY IN THE LARGE. Alfred Huber. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-72 (AFOSR TN 56-261), May, 1956. 92 pp. 33 refs. Treatment of problems pertaining to differential geometry in the large by function theoretical methods. Includes new proof and generalization of the Cohn-Vossen, Blanc, and Fiala theorems, and implies results for analytic functions and differentials.

ON SURFACES ON THE TYPE ν; ANALYTICAL THEORY OF CONTINUOUS TRANSFORMATIONS. Lamberto Cesari. Purdue U., Dept. Math., TN 3 (AFOSR TN 56-358), Apr., 1956. 76 pp. 13 refs. Discussion of the concept of retraction for continuous mappings $S=(T, A)$ from a finitely connected Jordan region $A=J$, or mappings, or surfaces of the ν-type, where ν is the connectivity of J, $0 \leq \nu < +\infty$. New features are observed for $\nu \geq 1$ which have no analogy to the case where J is a simple Jordan region ($\nu = 0$). A new concept of fine-cyclic element $\mathfrak{G}$ of a surface $S=(T, J)$ of the type ν is introduced as a retraction of S according to the concept of retraction, and the concept and properties of fine-cyclic elements are discussed in detail.

B-SETS AND FINE CYCLIC ELEMENTS; ANALYTICAL THEORY OF CONTINUOUS TRANSFORMATIONS. C. J. Neugebauer. Purdue U., Dept. Math., TN 4 (AFOSR TN 56-356), July, 1956. 38 pp. ARDC-supported study including an extension of Cesari's concepts to Peano spaces. Attempt is made to decompose a proper cyclic element by generalizing the concept of a set being cyclic, in order to develop a theory for the generalized elements as complete as the theory of proper cyclic elements of a Peano space.

ON THE ITERATED WAVE EQUATION. Dorothee Krahn. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN 73 (AFOSR TN 56-239), May, 1956.

31 pp. Establishment of a theorem on the decompositions of the general solution of the iterated wave equation in terms of solutions of the Euler-Poisson-Darboux equation, and derivation, through the use of a particular decomposition, of a solution to the Cauchy problem for the equation $L_0^n(w) = 0$ with initial conditions on the boundary $t = 0$. This method of solution is extended to deal with the Cauchy problem for a more general equation and it is shown that corresponding results hold true for the polyharmonic equation.

OSCULATORY EXTRAPOLATION AND A NEW METHOD FOR THE NUMERICAL INTEGRATION OF DIFFERENTIAL EQUATIONS. H. E. Salzer. J. Franklin Inst., Aug., 1956, pp. 111-120. Description of a procedure which is applicable for real functions and may be modified to give a newer, more compact, and, in certain respects, more accurate method for the stepwise numerical integration, over a Cartesian grid of length h, of differential equations of the form $w' = \phi(z, w)$, in a region of the complex plane where w(z) is an analytic function. The method is based on the Hermite osculatory interpolation formula used to extrapolate for functional values alone.

METEOROLOGY

SPECIAL ISSUE: A DISCUSSION ON RADIATIVE BALANCE IN THE ATMOSPHERE. Proc. Royal Soc. (London), Ser. A, Aug. 2, 1956, pp. 145-226. 178 refs. Contents: Introductory Remarks, H. S. W. Massey. The Patterns of Radiative Heating and Cooling in the Troposphere and Lower Stratosphere, F. Möller. The Computation of Radiative Heating Rates in the Atmosphere, A. R. Curtis. High-Resolution Spectroscopy of Minor Atmospheric Constituents, M. Migeotte. The Use of Surface Observations to Estimate the Local Energy Balance of the Atmosphere, G. D. Robinson. Solar Infra-Red Spectroscopy from High-Altitude Aircraft, F. E. Jones and V. Roberts. Some Measurements of the Flux of Infra-Red Radiation in the Atmosphere, A. W. Brewer and J. T. Houghton. Origin and Distribution of the Polyatomic Molecules in the Atmosphere, G. M. B. Dobson. Thermal Radiation in the Upper Atmosphere, A. R. Curtis and R. M. Goody. The Thermosphere, D. R. Bates. Study of Solar Radiation at High Altitudes Using Rocket-Borne Instruments, R. L. F. Boyd. Absorption of Ultra-Violet Radiation by the Atmospheric Gases, R. W. Ditchburn. Symposium directed toward developing a detailed understanding of the equilibrium and the factors which determine it, in order to assist meteorological prediction.

MISSILES

IMPROVED ON-OFF MISSILE STABILIZATION. R. W. Bass. Jet Propulsion, Aug., 1956, pp. 644-648, 643. 16 refs. Derivation of a procedure for on-off control systems by which the delays (due to time-lag and hysteresis in the system) can be completely eliminated. By generalization of a fundamental relationship, satisfied by any fundamental matrix of solutions of a system of homogeneous linear differential equations with constant coefficients, an explicit algorithm is developed to which the ideal feedback coefficients of a perfectly stabilized servosystem can be read directly from the equations of the corresponding conventional system. Applications are made to a jet reaction control system, to an aerodynamic control system, and to any system with three degrees of freedom.

OPTIMUM ROCKET TRAJECTORIES. B. D. Fried and J. M. Richardson. J. Appl. Phys., Aug., 1956, pp. 955-961. General considerations leading to the derivation of equations for the optimum attitude angle for both constant and Kepler force fields, the results of which provide a convenient means of estimating an upper limit for the achievable range of a given missile. Results of analyses, which are exact for a constant gravitational field (if aerodynamic forces and altitude dependence are neglected), indicate that the maximum range is achieved, under certain simplifying assumptions, if the thrust attitude angle is held constant during the entire powered flight, and that constant thrust attitude is a good approximation to the optimum program for motion in the earth's inverse square, central force field, provided the distance covered during powered flight is small compared to the radius of the earth.

NUCLEAR ENERGY

THE USE OF NUCLEAR RADIATION IN COMBUSTION RESEARCH. M. E. Gluckstein, R. B. Morrison, and J. V. Nehemias. Jet Propulsion, Aug., 1956, pp. 637-643. Analysis of the interaction of nuclear radiation with fuel-oxidant system causing increased rates of chemical reaction. The discussion includes design criteria, problems of handling radioactive materials, and possible applications of these radioactive materials. Based on simple models, the analysis shows that the reaction rate should be dependent upon the energy and activity of the radiation source. Only beta and alpha emitters are considered, since, for gas phase reactions or for reactors of relatively small size, they are the more efficient sources.

PHYSICS

THE STRENGTHS, WIDTHS, AND SHAPES OF INFRARED LINES. I - GENERAL CONSIDERATIONS. II - THE HCl FUNDAMENTAL. W. S. Benedict, Robert Herman, G. E. Moore, and Shirleigh Silverman. Can. J. Phys., Aug., 1956, pp. 830-875. 48 refs. USAF-ONR-supported analysis of methods for deriving the strengths, widths and shapes of spectral lines from measurements obtained with spectrometers having resolving power sufficient for separating individual spectral lines but insufficient for portraying the true contour line accurately. Detailed application of these methods to the vibration-rotation lines of the 1-0 bands of HCl^{35} and HCl^{37} observed at 300° K. is outlined. The Lorentz shape for collision-broadened lines is taken as a first approximation to the true line shape, and numerous corrections are included which arise from instrumental defects,

overlapping of the individual lines, and deviations from the Lorentz shape, and which should be taken into account in interpreting experimental data. The variation of the line strengths with rotational quantum numbers, obtained experimentally, is compared with theory to yield a value of the ratio of permanent electric dipole moment to the product of the effective charge and the equilibrium internuclear distance of +0.988+0.022.

DIFFRACTION BY A WIDE SLIT. S. N. Karp and A. Russek. J. Appl. Phys., Aug., 1956, pp. 886-894. 11 refs. USAF-sponsored theoretical investigation of the problem of diffraction of scalar waves by an infinite conducting plane with a slit. Approximate expressions for the near and far fields, taking into account the interaction between the edges, are derived in terms of the well-known solutions for the fields produced when an isolated conducting half-plane is excited by (a) a plane wave and (b) a line source. Includes numerical examples for the case of a plane wave normally incident on the slit.

POWER PLANTS

Jet & Turbine

TURBOJET CYCLE ANALYSIS: THE EFFECTS OF LIQUID INJECTION AT SEVERAL POINTS IN THE CYCLE. Appendix A---DERIVATION OF EQUATIONS. E. P. Cockshutt. Canada, NAE LR 164, Apr., 1956. 28 pp. Calculation of the effects for liquid injection both upstream and downstream of the turbine. The responses of the peak cycle temperature, engine fuel flow, tailpipe pressure, gross thrust and turbine pressure ratio are given for a range of liquid latent heats and gas Mach Numbers. The equations derived include working equations for pre-turbine and tailpipe injection, and relations between engine fuel flow and peak cycle temperature, and between engine thrust and tailpipe pressure. Results of analysis indicate that pre-turbine injection, unlike tailpipe injection, automatically requires that the engine be overheated when operating with a fixed propelling nozzle. Applicable to performance analysis of a reheated turbojet engine in which pre-turbine injection of the reheat fuel offers the advantage of cooling the turbine rotor blades by the impinging fuel.

A METHOD OF CORRECTION OF COMPRESSOR CHARACTERISTICS FOR CHANGE OF WORKING FLUID SPECIFIC HEAT. S. J. Moyes. Gt. Brit., NGTE Memo. M.276, July, 1956. 13 pp. Development of a method based on aerodynamic relationships for determining the effect of changes in specific heat on axial-flow compressor characteristics. Method is limited to cases where Mach Number effects in the compressor are not present or are small, and may be extended to cover working fluid properties other than specific heat. The basic assumption of the method is that the work input per unit mass flow depends only on blade velocities and the angles through which the working fluid is constrained to flow, and that the polytropic efficiency depends only on the latter. On this basis the overall performance for a new value of the working-fluid specific heat may be determined from that obtained with a former value by the linking of conditions having the same flow angles.

TURBINES DE SERVITUDES POUR L'ENTRAÎNEMENT D'ACCESSOIRES. Y. Conan. Tech. et Sci. Aéronautiques, No. 3, 1956, pp. 140-146. In French. Analysis of a pneumatic auxiliary system in which compressed air is obtained from the main power plant compressor. Derivation of formulas suggesting that the relationship between the specific air temperatures stays constant and equal to 1,4 and that the specific heat at constant pressure does not vary. Includes listing of main turbine manufacturers in USA, France, and Great Britain.

Ram-Jet & Pulse-Jet

LA REPRESENTATION GRAPHIQUE DES PHENOMÈNES SE PRESENTANT DANS LES CHAMBRES DE COMBUSTION ET STATORÉACTEURS. Otto Lutz. Tech. et Sci. Aéronautiques, No. 3, 1956, pp. 105-112. In French. Graphical presentation of phenomena encountered in combustion chambers and in ram-jets. The normalization of the diagram p, w, following the total energy, permits not only a simple extension for the state variation within cylindrical combustion chambers, but also methods of deformation, which can be used for determining the drop in the dynamic pressure of gases during a heat addition, or with shock waves. The diagram shows clearly the critical state during a heat addition, the coefficient of thrust, and the total efficiency, as well as the possible limiting state. The flight Mach Number M_{vol} is registered by the final representation, and thus permits the direct use of the diagram for an in-flight study.

Rocket

COMBUSTION PROCESSES IN LIQUID PROPELLANT ROCKET MOTORS (Third Quarterly Progress Report for the Period 1 March 1956 to 31 May 1956). I. E. Smith, and I. Glassman. Princeton U. Dept. Aero. Eng. Rep. 334-c, June 29, 1956. 12 pp. Experimental investigation, using a specially designed apparatus, to determine the effect of temperature, pressure, and relative particle velocity on the ignition delay time and rate of energy release. Includes a description of the apparatus, which uses a heated, inert material (N_2) as the carrier gas. An oil burner heats a packed ceramic bed to a desired temperature, and the nitrogen is then metered through and around the bed so that a wide range of gas temperatures may be obtained at the entrance to the test section. For the initial work, gaseous monopropellant is injected into the gas flowing in the test section from a simple boiler, and the decomposition reaction follows. Wall thermocouples in the test duct at six-inch intervals correct any gas temperature thermocouple within for radiation losses. Results of test runs injecting ethylene oxide into an inert stream with the probe manually traversed, are qualitative, and indicate that the course of the decomposition reaction can be followed

satisfactorily by this method, but that the cooling of the duct walls during the run causes an uncertainty in the true gas temperature condition, which can be corrected by heating the duct by means of an electrical winding with variable current supply. Preliminary work on the design of the slave motor and heat exchanger of a high pressure apparatus is outlined.

SOME TESTS OF INJECTORS FOR ROCKET MOTORS USING LIQUID OXYGEN. J. Humphries and W. H. J. Riedel. Gt. Brit., RAE TN R.P. D.140, Feb., 1956. 25 pp. Comparison of various injection systems on a 900 lb. thrust scale, in terms of economy of propellant consumption and of component manufacturing ease, as a step in the design of a 4000 lb. thrust liquid oxygen/kerosene aircraft rocket motor with variable thrust. The systems, which include the V2 design, the nonimpinging, and the peripheral slit types, are further compared with the similar systems operating with 75% ethyl alcohol/water fuel mixture. Results indicate that the shower and peripheral-slit types using kerosene as fuel operate satisfactorily without burning out.

PRODUCTION

Metalworking

SYNTHETIC-RESIN BONDING; THE USE OF REDUX AND ARALDITE ADHESIVES IN THE AUSTRALIAN JINDIVIK AIRCRAFT. I---CONSTRUCTIONS; BONDING TECHNIQUE; TOOLING METHODS. G. D. Bennett. Aircraft Prod., Aug., 1956, pp. 300-305. Discussion of the design considerations affecting the type of structure and the type of adhesive chosen. Heat treatment and the use of silicone rubber for vacuum blankets are also discussed.

LARGE FORGINGS; SOME OBSERVATIONS ON THEIR MANUFACTURE IN HIGH-STRENGTH ALUMINIUM-ALLOYS. C. Wilson. Aircraft Prod., Sept., 1956, pp. 374-382. Detailed consideration of heat treatment and an outline of manufacturing methods, in order to draw attention to the effects on reliabilitity and consistency of the heat-treatment process in developing an internal stress system. Rules are given for overcoming these effects.

ROTATING WING AIRCRAFT

THE AERODYNAMICS OF THE HELICOPTER IN FORWARD FLIGHT. E. N. Brailsford. J. RAeS, Aug., 1956, pp. 523-542. 16 refs. Solution for aerodynamic derivatives using the strip theory. Expressions for the determination of the rotor attitude are derived for obtaining a solution of the performance equation. A refined version of the Glauert energy solution is used for performance estimation. This version gives the numerical solutions for the rotor attitude relative to horizontal and incident flow, and is used for obtaining the components of velocity relative to the disc-plane. The effect of side tilt on the main rotor required to balance the torque reaction force is also considered. The local velocities at the rotor tip are resolved, using the previously computed vectors, and, finally, the elementary lift and drag equations are developed, taking into account the effects of sweep.

A STUDY FOR OPTIMUM CONDITION OF GYRODYNE TYPE ROTARY WING. Masato Hirotsu. J. Japan Soc. Aero. Eng., July, 1956, pp. 168-175. Analysis for determining the optimum condition in which a gyrodyne can fly faster than a helicopter or autogiro. As a reference flying state between extreme conditions, the inflow rate (λ) and the rotor angle of attack (α) are taken as zero. The optimum condition is treated as $\lambda + \mu\alpha_s = 0$ for the stall of retarding blade. This condition is deduced for blades without twist, and it is the condition in which the section angles of attack become constant at $\psi = 270^\circ$ and 90°.

STATIC-THRUST MEASUREMENTS OF THE AERODYNAMIC LOADING ON A HELICOPTER ROTOR BLADE. J. P. Rabbott, Jr. US, NACA TN 3688, July, 1956. 22 pp. Experimental investigation to obtain the chordwise pressure distributions at five spanwise stations on a 15-ft.-diameter helicopter rotor blade in static thrust for a tip speed range of 400 to 500 ft./sec. and disc loads of zero to about 2.5 lbs./ft.^{2}, and to compare the measured spanwise loading with a simple theoretical loading modified by an approximate correction for a finite number of blades. Results indicate that, while the chordwise pressure distributions are, in general, conventional in shape, the loading near the trailing edge of the outboard portion of the rotor is lower than expected from theory or from a comparison of the loading at the inboard stations. This lower loading is possibly due to a spanwise boundary-layer growth adding to the reduction of the total load expected from tip-loss considerations. The spanwise loading increases smoothly from the root toward the tip, with peak loads occurring at 90 to 95% radius and being farther inboard at the higher thrust coefficients, indicating a greater tip loss at these points.

STRUCTURES

THE RELATIONSHIP BETWEEN LOAD SPECTRA AND FATIGUE LIFE. Bo Lundberg and Sigge Eggwertz. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 67, 1956. 32 pp. 24 refs. Development of methods to correlate or evaluate fatigue life times using the cumulative damage theory or program testing. A preliminary investigation on accelerations of fighter planes and transports shows that the load spectra for both types do not represent widely differing load conditions with respect to fatigue, and that both can be approximated by a straight line in a semi-log plot. The important parameter of a straight line spectra is the slope; by using the cumulative damage theory the influence of this slope on the damage intensity curve and fatigue life of the element is investigated. Results show the possibility of standardizing the load spectra for program tests in the form of straight lines on semi-log paper. With such stand-

ardization the results of program testing can be characterized as properties of materials or components of about the same basic nature as the S-N properties.

Beams & Columns

FATIGUE-CRACK PROPAGATION IN ALUMINUM-ALLOY BOX BEAMS. H. F. Hardrath, H. A. Leybold, C. B. Landers and L. W. Hauschild. US, NACA TN 3856, Aug., 1956. 33 pp. Experimental investigation of 18 box beams constructed according to four designs - two with stiffeners riveted to the cover, one with stiffeners bonded to the cover, and one with an integrally stiffened cover machined from a plate. Two or more specimens of each design are built from each of the aluminum alloys 2024-T3 and 7075-T6. Results indicate a more rapid crack-propagation rate in specimens made of the 7075-T6 material than in equivalent specimens of 2024-T3 tested at the same nominal stress; lower crack-growth rate in the specimens with bonded stringers than in the other specimens; and the most rapid crack-propagation rate in specimens with integrally stiffened covers. Data is discussed with the aid of stress-survey data obtained during the tests.

Cylinders & Shells

CIENKOSCIENNA POWŁOKA TOROIDALNA OBCIĄŻONA RÓWNOMIERNYM CIŚNIENIEM. Aleksander Kornecki. Rozprawy Inżynierskie (Warsaw), No. 1, 1956, pp. 119-172. 19 refs. In Polish. Method for the approximate computation of stress and strain components in a thin-walled toroidal elastic shell of circular cross-section, limited by two parallels and loaded with uniform pressure. The problem is reduced to the determination of a complex function satisfying the differential equation derived by means of the Novozhilov's complex stress method. The particular solution of the non-homogeneous problem is expressed in closed form by means of Bessel functions. The exactness of this method increases with decreasing wall thickness.

STATECZNOŚĆ POWŁOKI WALCOWEJ WZMOCNIONEJ ŻEBRAMI. W. Nowacki and Z. Olesiak. Rozprawy Inżynierskie (Warsaw), No. 1, 1956, pp. 3-22. In Polish. Analysis of the buckling problem of a cylindrical shell with longitudinal and transverse ribs using the differential equations of the Vlasov engineering theory of shells. The solution is obtained by means of a double trigonometric series which leads to a double system of equations. By taking the determinant of the system set equal to zero, the solution to the buckling condition is obtained. Some examples are presented. For a shell built in at one to four edges, an approximate solution is obtained. More particular problems investigated include a shell with one or two transverse ribs only, and a shell with one longitudinal rib. In these problems discussed are shells with a uniformly distributed load (q) or loaded by forces on the ribs (S). Solutions are also presented for the case of a shell reinforced with a dense net of ribs either longitudinal or transverse, and a shell with a dense net of ribs plus one particularly rigid rib.

Elasticity & Plasticity

CREEP RELAXATION FOR COMBINED STRESSES. J. E. Griffith and Joseph Marin. J. Mech. & Phys. Solids, Aug., 1956, pp. 283-293. 12 refs. Development of a theory for predicting stress relaxation-time relations for creep in the case of combined stresses based on an assumed constant stress-creep-time relation. Relations are developed for three different cases, and accuracy of the predictions are checked experimentally by conducting some creep relaxation tests on thin walled circular tubes subjected to combined axial tension and torsion. The material tested is aluminum alloy 3S-0, and the results indicate approximate agreement between the theory proposed and the tests.

COMPRESSIVE AND TORSIONAL BUCKLING OF THIN-WALL CYLINDERS IN YIELD REGION. Appendix A - PLASTICITY CONSIDERATIONS. Appendix B - EQUILIBRIUM CONSIDERATIONS; ELASTIC BUCKLING. Appendix C - AXIAL COMPRESSIVE BUCKLING OF A LONG CYLINDER. Appendix D - TORSIONAL BUCKLING OF A LONG CYLINDER. George Gerard. US, NACA TN 3726, Aug., 1956. 42 pp. 22 refs. Theoretical and experimental investigation, with analysis using deformation stress-strain relations and a no-strain-reversal buckling model to derive a general set of equilibrium differential equations for plastic buckling of circular cylinders and the plasticity-reduction factors for inelastic buckling of long cylinders under compressive or torsional loadings.

SPRĘŻYSTO-PLASTYCZNA GRUBOŚCIENNA POWŁOKA KULISTA Z MATERIAŁU NIEJEDNORODNEGO, PODDANA DZIAŁANIU CIŚNIENIA WEWNĘTRZNEGO I ZEWNĘTRZNEGO. W. Olszak and W. Urbanowski. Rozprawy Inżynierskie (Warsaw), No. 1, 1956, pp. 23-41. In Polish. Study of thick-walled elasto-plastic spherical shells of non-homogeneous material, subjected to internal and external pressure. Analysis to determine the value of the pressure difference corresponding to the first plastic deformations at the internal surface of the shell, and the value corresponding to the plastification of the whole shell.

OB URAVNENIIAKH PLASTICHESKOGO TECHENIIA V POGRANICHNOM SLOE. V. V. Sokolovskii. Prikl. Mat. i Mekh., May-June, 1956, pp. 328-334. In Russian. Study of plastic flow in the immediate vicinity of the boundary curve, along which the contacting tension equals the flow limit. In a certain narrow boundary it has specific characteristics which are investigated in curvilinear coordinates corresponding to the shape of the boundary curve.

ON THE PROBLEM OF UNIQUENESS IN THE THEORY OF A RIGID-PLASTIC SOLID. I. R. Hill. J. Mech. & Phys. Solids, Aug., 1956, pp. 247-255. Theoretical analysis of a rigid-plastic system. The yield point of such a system is defined by spec-

ifying the velocity over a part of the surface (S_V), and the traction over the remainder of the surface (S_f). These boundary conditions determine uniquely the state of stress in a certain part of the plastic zone but not usually the instantaneous mode of deformation. This is specified by the traction-rate over S_f, which is sufficient to define the mode uniquely within certain continuity restrictions when the material work-hardens and when changes in geometry are negligible. The appropriate mode in a nonhardening solid is obtained by a limiting process in which the rate of hardening is made vanishingly small.

Plates

INEQUALITIES FOR EIGENVALUES OF SUPPORTED AND FREE PLATES. L. E. Payne. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN 75 (AFOSR TN 56-281), June, 1956. 25 pp. 15 refs. Derivation of certain isoperimetric inequalities for the eigenvalues in the classical vibration and buckling problems in supported and free plates. These inequalities involve the geometry of the plate and the eigenvalues of membranes having the same shape as the plate. It is shown that if the boundary is convex the eigenvalues of the supported plate are never greater than the corresponding eigenvalues of the fixed membrane of the same shape.

Testing

INVESTIGATIONS INTO A PHOTOELASTIC METHOD FOR DIRECT MEASUREMENT OF SURFACE STRAINS IN METAL COMPONENTS. J. R. Linge. Coll. of Aeronautics, Cranfield, Rep. 97, Feb., 1956. 55 pp. 37 refs. Includes description of the technique which consists of an examination of surface strains with optically sensitive materials bonded to the component and of an analysis of the photoelastic pattern produced under load by means of polarized light reflected from the surface of the metal. Consideration is given to the fundamental problem of producing good adhesion between the photoelastic material and the metal surface, coupled with light reflection from this surface. Results of measurement of both elastic and plastic stress concentrations at holes in plates subjected to uniform tension are presented together with a qualitative analysis of the effect on stress distribution of the variation of the pin-to-hole clearance in lugs.

Thermal Stress

FUNDAMENTAL PRINCIPLES AND THEOREMS OF THERMO-ELASTICITY. W. S. Hemp. Aero. Quart., Aug., 1956, pp. 184-192. Outline of foundations of thermo-elasticity and derivation of generalizations of the usual variational theorems used in structural analysis. The deformation, stress, and temperature distribution are calculated as functions of time. The heat conduction in the body is analyzed in order to determine the temperature distribution. Once the temperature distribution is known, the stress and deformation are found by generalization of the stationary potential energy theorem and of the Castigliano theorem of stationary strain energy.

O POZIOMYM ODDZIAŁYWANIU SPRĘZYSTEGO PODŁOŻA NA PŁYTY PODDANE DZIAŁANIU ZMIAN TEMPERATURY. Zygmunt Thrun. Rozprawy Inżynierskie (Warsaw), No. 1, 1956, pp. 87-97. In Polish. Derivation, for a plate resting on an elastic foundation, of differential equations for deflection, bending and twisting moments, and shear and normal forces, taking into account temperature changes within the plate and the horizontal reaction of the elastic foundation.

ODKSZTAŁCENIA I NAPRĘŻENIA TERMICZNE W PŁYTACH NA SPRĘŻYSTYM PODŁOŻU. Zygmunt Thrun. Rozprawy Inżynierskie (Warsaw), No. 1, 1956, pp. 71-86. In Polish. Application of the method of finite differences to the determination of thermal stresses and strains in plates. It is assumed that the temperature difference between the upper and the lower layer of the plate is constant for the whole area of the plate. The differential formulas obtained for deflections, bending moments, and shearing forces refer to rectangular plates arbitrarily supported and to circular plates on circularly symmetric supports. Two examples are given to illustrate the computational procedure.

Weight Analysis & Control

NONLINEAR MINIMUM-WEIGHT DESIGN OF PLANAR STRUCTURES. L. G. Vargo. J. Aero. Sci., Oct., 1956, pp. 956-960. Development of a method for determining the minimum-weight, fully plastic moments of a planar structure subject to a set of concentrated loads. A general nonlinear relationship between fully plastic moments and areas of the series of sections available to the designer is included in the method. Solutions for a two-span beam and a rectangular bent under concentrated loads are presented, and comparison is made with the results of a linearity assumption. When geometrically similar sections are used, the linearity assumption results in up to a 15% weight penalty.

THERMODYNAMICS

OB USLOVIAKH VOZNIKNOVENIIA KONVEKTSII V BINARNOI SMESI. B. A. Vertheim. Prikl. Mat. i Mekh., Nov.-Dec., 1955, pp. 745-750. In Russian. Study of some convection phenomena occuring in binary mixtures. Derivation of equilibrium conditions for unevenly heated binary mixtures and of equations of small turbulences. The problem of stationary convection in vertical cylinders is solved in closed form, taking into account Ostroumov's solution for a related problem considering the ideal media.

Heat Transfer

HEAT TRANSFER FROM A ROTATING DISK. E. C. Cobb and O. A. Saunders. Proc. Royal Soc. (London); Ser. A, Aug. 2, 1956, pp. 343-351. 11 refs. Experimental investigation for obtaining accurate measurements over a range of speeds giv-

ing purely laminar conditions at one extreme and turbulent conditions over most of the disc at the other extreme. Includes measurements of the velocity and temperature profiles for both the laminar and turbulent conditions, and a discussion of the relation between heat transfer and friction torque. Experimental heat-transfer results agree with Wagner's theoretical conclusions for laminar flow, but Millsap's estimates are found to be too low. Results further indicate that heat transfer for the turbulent case approaches the expression $N = 0{\cdot}015R^{0.8}$ for all-turbulent flow. Measured velocity and temperature-profile values for laminar flow are in fair agreement with those theoretically obtained. For turbulent flow the temperature ratios are found to be higher than those of velocity.

Thermodynamic Properties

COMPRESSIBILITY FACTOR, DENSITY, SPECIFIC HEAT, ENTHALPY, ENTROPY, FREE-ENERGY FUNCTION, VISCOSITY, AND THERMAL CONDUCTIVITY OF STEAM. Lilla Fano, J. H. Hubbell, and C. W. Beckett. US, NACA TN 3273, Aug., 1956. 61 pp. 43 refs. Thermal properties of steam are given over the following ranges: compressibility factor and density from pressures of 1 to 300 atmospheres; temperatures from 380° K., or just above condensation to 850° K.; viscosity and thermal conductivity as functions of pressure; and specific heat, enthalpy, entropy, and free energy function for pressures ranging from 1 to 100 atmospheres, and for temperatures up to 850° K.

WIND TUNNELS & RESEARCH FACILITIES

DESIGN OF AN AIR SUPPLY SYSTEM AND TEST SECTION FOR RESEARCH ON SCAVENGING SYSTEMS FOR PROPULSION WIND TUNNELS. Appendix A - TEST SECTION SIZING. Appendix B - SUPERSONIC SECTION. Appendix C - DIFFUSER EJECTOR. Appendix D - AIR DRYING. J. G. Wilder, Kenneth Hindersinn, and Roger Weatherston. USAF WADC TR 56-6, May, 1956. 56 pp. 16 refs. USAF-sponsored design of an air supply system suitable for driving supersonic or transonic test sections of approximately 1 ft.^{2} area and of a 10 in. x 14.4 in. supersonic and a 10 in. x 12 in. transonic test sections. The system is constructed to allow maximum geometrical flexibility for research on wind-tunnel design and performance. The supersonic test section is adapted to experimental studies of scavenging systems and to research on diffuser efficiency and losses, interaction of the scavenging system and diffuser, nozzle characteristics and performance, and second throat configurations. The transonic test section is equipped with a sting support for mounting models and with strain gage force measuring equipment as well as model pressure measuring equipment.

COMPRESSORS FOR HIGH-SPEED WIND TUNNELS. Appendix I - THE INFLUENCE OF PREROTATION VANES ON THE TORSIONAL VIBRATION OF WIND TUNNEL FAN BLADES. Appendix II - THE INFLUENCE OF PREROTATION VANES ON THE LATERAL VIBRATION OF WIND TUNNEL FAN BLADES. A. A. Fejer and James Clark. NATO AGARDograph 14, Jan., 1956. 216 pp. 119 refs. Analysis of compressor systems for wind tunnels designed for continuous operation. This includes aerodynamics of the tunnel circuit, taking into account their influence on the overall tunnel performance, a selection method to choose a compressor type, five methods to extend the range of drive systems, power requirements, and types of drives. Also includes starting and surge problems within a wind tunnel, mechanical design of compressors and their drives, vibration problems in the compressor and drive, and structural and aerodynamic models used to furnish information on performance of components and one design feature for which there is not enough existing information.

STUDIES ON WAKE VORTICES. II---EXPERIMENTAL INVESTIGATION OF THE WAKE BEHIND CYLINDERS AND PLATES AT LOW REYNOLDS NUMBERS. Sadatoshi Taneda. Kyushu U., Rep. Res. Inst. Appl. Mech., Oct., 1955, pp. 29-40. 10 refs. Photographic investigation over a Reynolds Number range of 0.1--2,000 to determine the critical Reynolds Numbers at which (a) twin vortices appear at the rear of a circular cylinder and (b) at which oscillation of the vake behind such a cylinder begins; (c) to verify the solutions of Navier-Stokes equations even in the case of R = 40; (d) to observe the wake behind flat plates parallel to the direction of motion; and (e) to develop and apply a new method for clarifying the structure and nature of the von Kármán vortex street. Clear streamlines are obtained for investigation (a) through the use of long photographic exposure. Results of experiment (b), using the reflection of light from aluminum dust suspended in the water, indicate that the wake commences oscillation at about R = 30, and that the twin vortices are independent, at least directly, of the oscillation of the wake. The series of experiments (c) employs a model coated with condensed milk to permit clear observation of the position of separation point and the structures of the twin vortices. Results of investigation (d) indicate that, in the case of the flat plate, twin vortices do not appear, and those obtained through the use of the new experimental method (e) (a combination of the aluminum dust and condensed milk procedures), reveal that sometimes the von Kármán vortex street is deformed in time and eventually disintegrates in pieces, the pieces reuniting after an interval to form a larger vortex street. At other times, it is noted, the primary vortex street develops into turbulent flow directly.

LOADS ON A MODEL DURING STARTING AND STOPPING OF AN INTERMITTENT SUPERSONIC WIND TUNNEL. K. G. Winter and C. S. Brown. Gt. Brit., RAE TN Aero. 2453, May, 1956. 17 pp. Measurements of loads at Mach Numbers 2.00 and 2.48. Qualitative agreement is obtained with a simple shock compression theory at Mach Numbers up to 2.5, but results indicate a need for further measurements at higher Mach Numbers and for analysis using a model-loading coefficient in terms of tunnel stagnation pressure.

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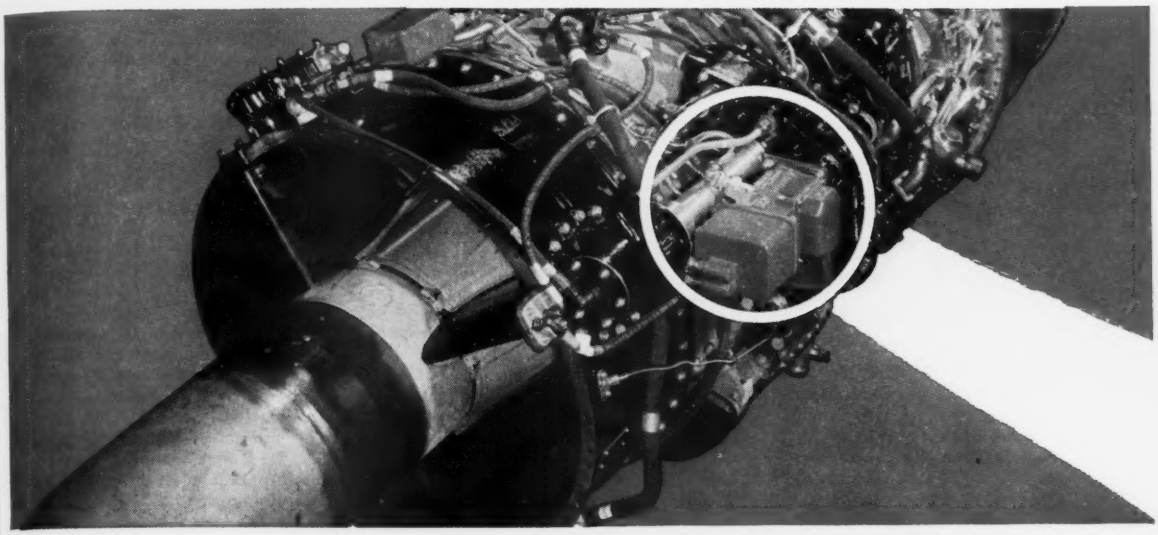

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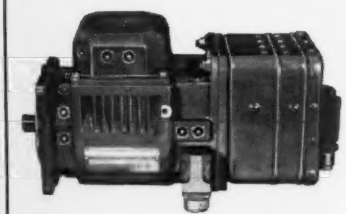

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placed on the stress-strain constant time diagram, otherwise known as an isochronous stress-strain diagram.

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Advances in Gas Turbine Materials. Julius J. Harwood. *Aero. Dig.*, Aug., 1956, pp. 20–27. Review of the search for materials capable of withstanding the high temperatures produced in gas turbines.

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Metals & Alloys, Nonferrous

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Design Factors for Extruded Rubber. Thomas O. Mathues. *Mach. Des.*, July 12, 1956, pp. 126–130. Discussion of rubber compounds for extrusion and of the design of extruding dies, taking into account swelling of the compound as it leaves the extruder and the shrinkage during the curing period.

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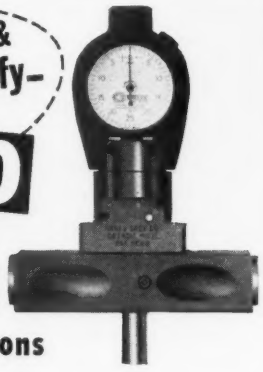

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reed method and of a number of dynamic tests in which stress or strain is applied sinusoidally. Includes analysis of the data obtained through tests to provide valid dynamic moduli. Methods are applicable to the determination of both the real and imaginary components of the dynamic modulus.

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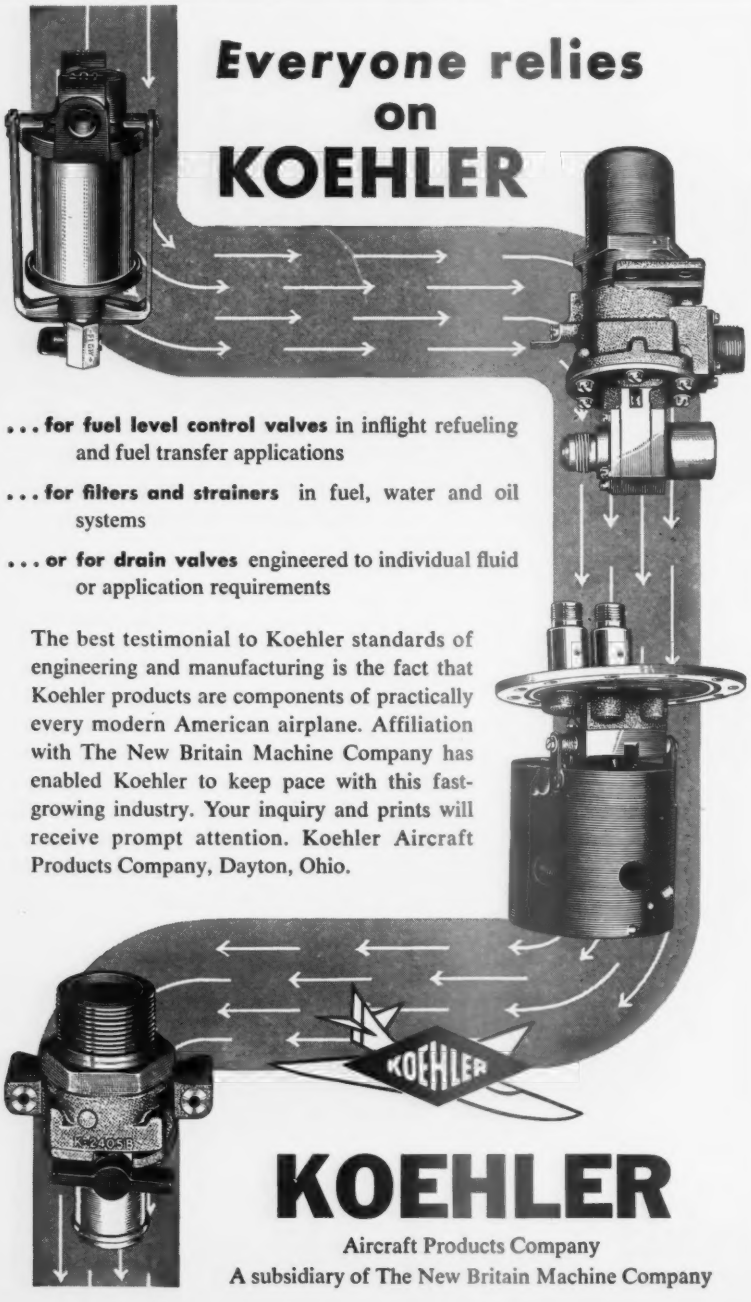
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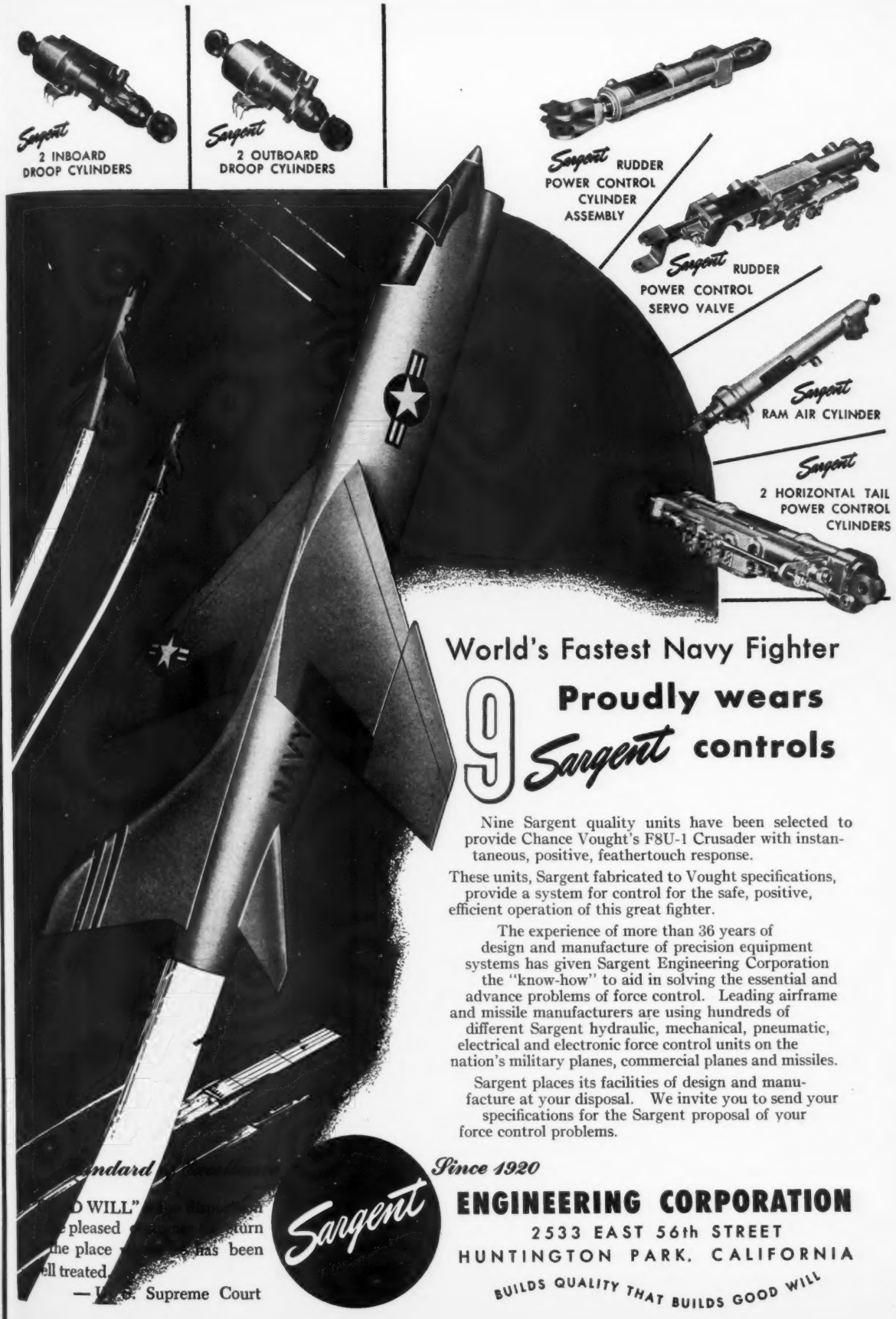

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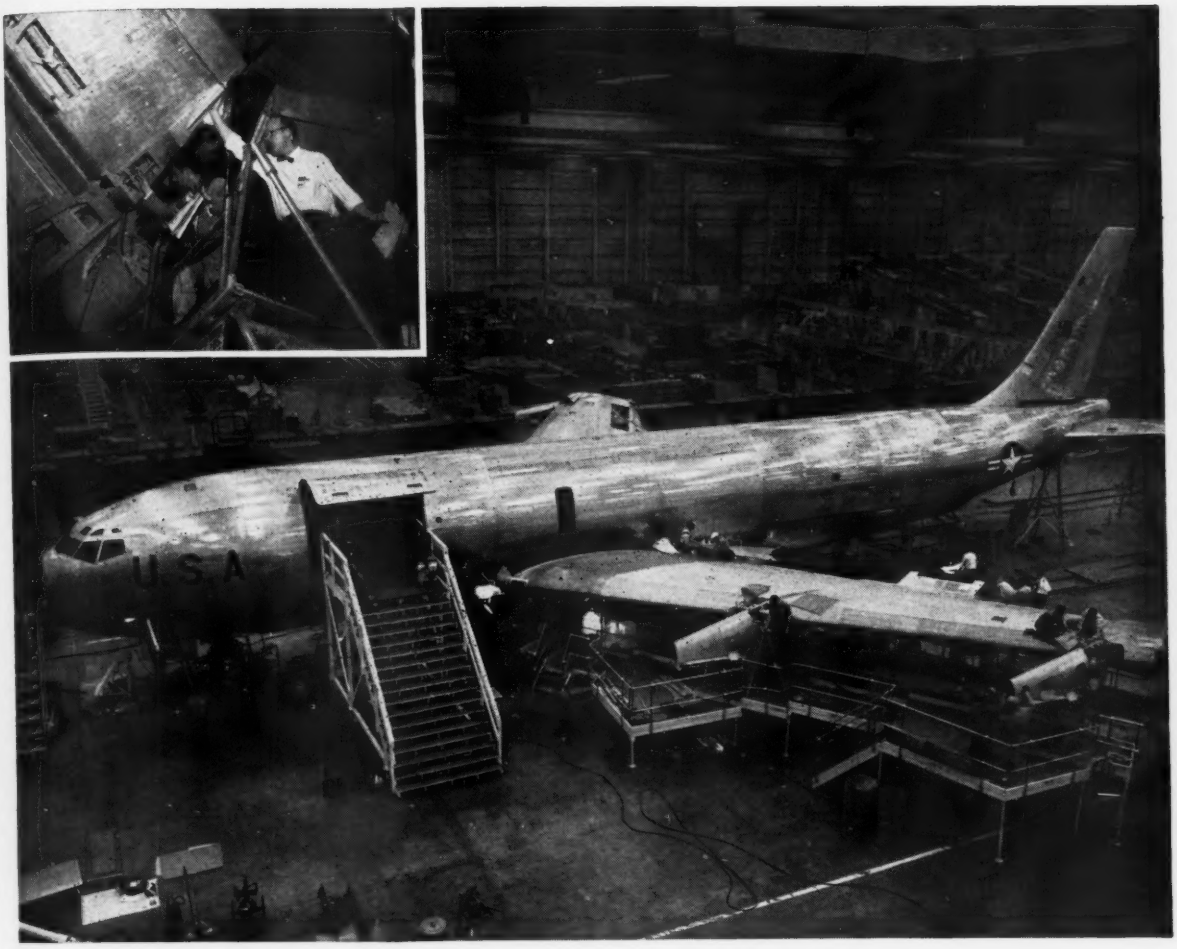
Flight Investigation of the Performance of a Two-State Solid-Propellant Nike-Deacon (Dan) Meteorological Sounding



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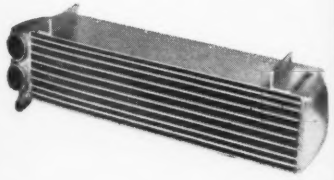

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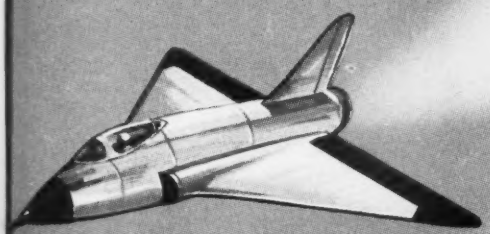

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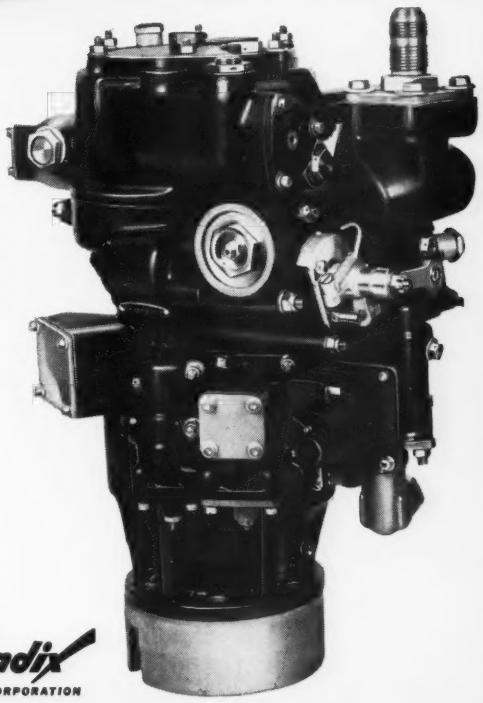

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Carbon Formation from Acetylene in the Shock Tube. E. N. Bennett. *CIT Gug-*

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Vertical Take-Off Aircraft

Variety of VTOL Aircraft Types Now Feasible. K. S. Coward, E. R. Hinz, R. J. Woods, and Charles H. Zimmerman. (*SAE Natl. Aero. Meeting, New York, Apr. 11, 1956, Paper.*) *SAE J.,* July, 1956, pp. 68–74. Abridged. Discussion of VTOL aircraft including analysis of fundamentals of direct lift, and types, performance, and capabilities of the VTOL aircraft.

Senkrecht startende Flugzeuge; Der Coleopter, eine Optimallösung. Heinrich Hertel. *Luftfahrttechnik,* Oct. 15, 1955, pp. 98–108. In German. General survey of VTOL design specifications, with power-plant, load, stability and control considerations, and aerodynamic and static characteristics of a circular-wing aircraft.

Water-Borne Aircraft

Ultraschallwelle am Tragflügelprofil bei Hohlsog. I. F. Numachi. *Forschung Gebiete Ing., Ausg. A,* No. 3, 1956, pp. 77–84. In German. Measurements of the frequency spectra of ultrasonic waves emitted by cavitation occurring on hydrofoils at various angles of incidence.

Preliminary Investigation of Self-Excited Vibrations of Single Planing Surfaces. Elmo J. Mottard. *U.S., NACA TN 3698,* June, 1956. 19 pp. Tests on a practical hydro-ski configuration to determine the effects of varying some of the structural and geometric properties and to determine the degrees of freedom required for the vibrations to occur.

Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings—Hydrodynamic Stability. XII—The Effect of Afterbody Angle on Stability and Spray Characteristics. XXI—Some Notes on the Effect of Waves on Longitudinal Stability Characteristics. D. M. Ridland. *Gt. Brit., ARC CP 236, ARC CP 237* (Feb., Aug., 1955), 1956. 31, 58 pp. 33 refs. BIS, New York, $0.81, $1.44.

The Hydrodynamic Characteristics of Modified Rectangular Flat Plates Having Aspect Ratios of 1.00, 0.25, and 0.125 and Operating Near a Free Water Surface. Kenneth L. Wadlin, John A. Ramsen, and Victor L. Vaughan, Jr. *U.S., NACA Rep. 1246,* 1955. 50 pp. Supt. of Doc., Wash. $0.40.

Wind Tunnels & Research Facilities

Laboratories et Productivité. M. G. Gilles and M. J. Cartier. *Tech. et Sci. Aéronautiques,* No. 2, 1956, pp. 71–77. In French. Discussion of test facilities installation, testing procedures, and exploitation of obtained results. Application is to various types of research.

NACA Transonic Wind-Tunnel Test Sections. Ray H. Wright and Vernon G. Ward. *U.S., NACA Rep. 1231,* 1955. 38 pp. Supt. of Doc., Wash. $0.40. Results of tests based on an approximate subsonic theory for the solid-blockage interference in circular wind tunnels with walls slotted in the direction of the flow in order to prevent the choking phenomenon characteristic of closed tunnels.

Transonic Wind Tunnel Test Sections. Paul F. Maeder and Albert D. Wood. *ZAMP,* May 5, 1956, pp. 177–212. 48 refs. OSR-sponsored review of the flow phenomena in transonic wind tunnels taking into account blockage, angle of incidence, buoyancy, and streamline curvature interferences.

Planning for Hypersonic Wind Tunnels. Yusuf A. Yoler. *Aero Dig.,* July, 1956, pp. 62, 63. Discussion of shock tunnels, gun tunnels, and electric mass accelerators for hypersonic testing.

La Construction et le Calibrage d'une Soufflerie Supersonique dans Laquelle il est Possible de Faire Varier le Nombre de Mach d'une Façon Continue. M. John Rosén. *Tech. et Sci. Aéronautiques,* No. 2, 1956, pp. 81–84. In French. Design and calibration of a supersonic test

(*Continued on page 175*)

Aeronautical Reviews — BOOKS

AERODYNAMICS

Supersonic Inlet Diffusers and Introduction to Internal Aerodynamics. Rudolf Hermann. Minneapolis, Aeronautical Division, Minneapolis-Honeywell Regulator Co., 1956. 378 pp., illus., figs., tables. $16.

The requirements of high diffuser efficiency in supersonic flight of turbojet and ram-jet power plants has heretofore not been given systematic and comprehensive treatment in a single volume. Dr. Hermann, who serves as a consultant to the Aeronautical Division, Minneapolis-Honeywell Regulator Company, has filled this need in a text directed toward the scientists and engineers who work with inlets and inlet-control problems and in the field of internal supersonic aerodynamics. The basic fundamentals of one-dimensional, two-dimensional, and axially symmetric diffusers are analyzed and wherever possible substantiated by experimental investigations. Many of these were performed by the author at the Rosemount Aeronautical Laboratories, University of Minnesota, where he is Professor of Aeronautical Engineering. One hundred and fifty full-page schematics, shadowgraph flow pictures, tables, and graphs appear in the text which also includes four pages of references to previously published material on supersonic diffusers.

Contents: (1) Various Diffuser Types, Their Functions and Applications in Supersonic Aerodynamics. (2) Diffuser with the Normal Shock in Front: Flow Process Efficiency and the Starting or Swallowing Process in One-Dimensional Analysis. (3) Diffuser with the Normal Shock Swallowed: Flow Process and Efficiency in One-Dimensional Analysis. (4) The Two-Dimensional Symmetric Multiple Shock Diffuser with a Wedge of Constant Angle Installed in a Duct. (5) The Two-Dimensional Multiple Shock Inlet Diffuser with Equal Upper and Lower Wedge Angles. (6) Analysis of a Two-Dimensional Multiple Shock System for Optimum Pressure Recovery. (7) Comparative Evaluation of Two-Dimensional Unsymmetric Multiple Shock Inlet Diffusers Composed of Wedges with Unequal Angles or Angular Steps. (8) The Axially Symmetric Spike Inlet Diffuser-Basic Analysis of On-Design Mach Number Operation. (9) The Axially Symmetric Spike Inlet Diffuser-Experimental Data and Comparison with Analysis. Appendix of Numerical Tables. References. Terminology. Index.

Principles of Turbomachinery. D. G. Shepherd. New York, The Macmillan Company, 1956. 463 pp., diagrs. $10.

An outline of the guiding principles underlying all forms of turbomachines, with a more detailed analysis of the most important particular types from the viewpoint of the mechanical engineer. Turbomachinery includes, in this volume, pumps, fans, compressors, and steam, gas, and hydraulic turbines. The author, Professor of Mechanical Engineering, Cornell University, has two objectives in the handling of the material. The first is a general treatment of all forms of turbomachines, covered by the chapters on dimensional analysis, energy transfer, thermodynamics of compressible flow, and the flow of fluids in the passages and over the blades of turbomachines. The second objective is the application of these principles to the several kinds of pumps, compressors, and turbines in sufficient detail to allow the major design and performance factors to be appreciated. No attempt has been made to introduce design from the mechanical standpoint. Intended as a textbook, a knowledge of fluid dynamics and thermodynamics has been assumed, but in most cases the particular expressions required have been recapitulated briefly.

The Structure of Turbulent Shear Flow. A. A. Townsend. London, New York, Cambridge University Press, 1956. 315 pp., diagrs. $7.50.

This is an attempt at a systematic and comprehensive discussion of all kinds of turbulent motion and an analysis of the processes which occur. Dr. Townsend, Professor at Emmanuel College, Cambridge, develops a unified view of the dynamics and shows how it accounts quantitatively for both the mean motion and the turbulent motion in jet, wake channel, boundary layer, and rotating cylinder flow. Many of these flows are important factors in meteorology, oceanography, astrophysics, chemical engineering, and aeronautics. The book is of potential value to graduates in university departments of mathematics, engineering, and physics, to the staffs of many research laboratories, and to the theoretician, since it presents the experimental data and basic ideas that any mathematical analysis of turbulent motion must take into account.

Contents: (1) Introduction. (2) The Equations of Motion in Shear Flow. (3) Flows Without Appreciable Variation of Mean Velocity. (4) Uniform Distortion of Homogeneous Turbulence. (5) Free Turbulence: Unrestricted Shear Flow. (6) Free Turbulence: Motion of the Large Eddies. (7) The Turbulent Wake. (8) Turbulent Jets. (9) Turbulent Flow in Pipes and Channels. (10) Boundary-layer Flow Without Pressure Gradient. (11) Boundary-layer Flow in a Pressure Gradient. (12) Shear Flow between Rotating Cylinders. Bibliography. Index.

Proceedings of the 4th Midwestern Conference on Fluid Mechanics; Held at Purdue University, September 8–9, 1955. (Purdue University, Engineering Experiment Station, Bulletin No. 128.) Lafayette, Ind., Purdue University, 1955. 370 pp., illus., diagrs. $6.00.

Contents: Summary of Turbulence Measurements in the NACA Lewis 6-by-60-Inch Boundary-Layer Channel, Virgil A. Sandborn. Calibration of a Hot Wire Anemometer for Low Velocities in Steady Flow with Temperature Gradients, L. A. Hromas and C. P. Kentzer. Nonisoenergetic Turbulent Compressible Jet Mixing with Consideration of its Influence on the Base Pressure Problem, R. H. Page and H. H. Koost. Measurements of the Energy Separation in a High Velocity Vortex Type Flow, E. R. G. Eckert and J. P. Hartnett. On the Integration of a Class of Differential Equations Occurring in Boundary Layer and Other Problems, Henry E. Fettis. Momentum and Energy Equations for Incompressible Turbulent Flow, Tien-To Siao. On the Use of Thermodynamic Concepts in Fluid Mechanics, F. Landis. A Theoretical Investigation of Turbulent Boundary Layer Flow with Heat Transfer at Supersonic and Hypersonic Speeds, Jerome Persh. Application of Piston Theory to Certain Elementary Aeroelastic Problems, Garabed Zartarian, Alfred Heller, and Holt Ashley. The Boundary Layer Development on a Broad Crested Weir, J. W. Delleur. The Flow Through Slits, B. A. Bakhmeteff and N. V. Feodoroff. Wave Resistance on Trailing Ships, A. G. Strandhagen and F. M. Kobayashi. Forces Acting on a Submerged Body Moving Under Waves, B. V. Korvin-Kroukovsky. On the Mechanism of Turbulent Flow in a Liquid, Robert L. Evans. Transonic Lift over the Front Surface of a Symmetric Diamond Wedge, Robert W. Truitt. Hypersonic Viscous Flow over a Wedge, S. I. Pai and S. F. Shen. Hypersonic Viscous Flow on Noninsulated Flat Plate, Ting-Yi Li and H. T. Nagamatsu. The Second Rhombus of a Supersonic Free-Jet Wind Tunnel as a Region of Variable Mach Number, J. D. Lee, R. H. Miller, and G. L. Von Eschen. Free Flight Boundary Layer Transition Studies on Cones, W. R. Witt, Jr. Fluid Motion in a Circular Vortex Ring, John Krosbein. Evaporation from Sprays, Walter Daskin. A Generalized Method of Computing the Influence of Spacing and Stagger on the Velocity Distribution of a Profile in a Cascade, F. S. Weinig. The Induction of Flow by an Injector Nozzle, John D. Lee.

Molecular Flow of Gases. G. N. Patterson. New York, John Wiley & Sons, Inc., 1956. 217 pp., illus., diagrs. $7.50.

In this book, the characteristics of a gas flow are determined from an assumed molecular model and the distribution of the velocities of the molecules. No attempt is made to give a complete treatment of either gas dynamics or the kinetic theory of gases. The primary purpose is to present a transition from the continuum to the molecular. Some discussion of strong shock waves is included in which effects arising from more complex molecules are considered. Intended for engineers and physicists, the level of mathematics employed does not differ greatly from that normally required in the continuum theory of fluid mechanics. The text is a result of 7 years of lectures to advanced students in engineering, physics, and applied mathematics at the University of Toronto, where the author is Director, Institute of Aerophysics, and Chairman, Department of Aeronautical Engineering and Aerophysics, School of Graduate Studies.

Contents: (1) The Fundamental Equations. (2) Isentropic Flow. (3) Basic Equations for Nonisentropic Flow. (4) Nonisentropic Flows.

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Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

(5) Mechanics of Rarefied Gases. Appendix. Index.

The Generation of Electricity by Wind Power. E. W. Golding. New York, Philosophical Library, Inc., 1956. 318 pp., illus., maps, tables. $12.

A detailed account of the research and development work done in Great Britain and other countries in an effort to harness wind power for the generation of electricity on a significant scale. Three aspects of the subject are developed—wind behavior and its determination, wind-driven machines, and the economic use of wind power under different conditions. Selected bibliographies are given at the end of each chapter, and the appendixes comprise a comprehensive list of meteorological references and a three-language (English, French, German) glossary of wind-power terms. The author is in charge of the Rural Electrification and Wind Power Department of the Electrical Research Association in Britain.

CAREERS

Your Career as an Engineer in Aviation. New York, Institute of the Aeronautical Sciences, Inc., 1956. 20 pp., illus., diagrs.

The complexities of today's aircraft demand the varied services of the mathematician, the physicist, and the electrical, chemical, mechanical, metallurgical, and electronics engineer. For the student planning a career, this booklet describes the field of aviation and the part engineers and scientists play in it. In this booklet will be found the "Subject Requirements for Admission to College," followed by a brief description of the costs of education. "Two Typical Programs of Study" covering the complete undergraduate degree are outlined, and finally there is a listing of engineering colleges in the United States, Alaska, and Hawaii.

DOCUMENTATION

Machine Literature Searching. James W. Perry, Allen Kent, and Madeline M. Berry. New York, Interscience Publishers, 1956. 162 pp., diagrs. $4.00.

In all fields of science, the literature is now so enormous and is growing so rapidly that a literature search can be an arduous and unsatisfying undertaking. This book describes the theory underlying searching machines and the technique of making the best use of them. For a number of years, the authors have been studying and developing new methods for analyzing, indexing, and coding the subject content of graphic records so that machine searching may be applied to its selection and retrieval. The 15 essays offer no universal solution; rather, they explore the fundamental principles that are essential to a better understanding of mechanized bibliographic organization as it is influenced by and related to such problems as proper machine design, indexing, terminology, code development, semantic units, definition, and operational criteria.

National Bibliographical Services, Their Creation and Operation. Knud Larsen. (UNESCO Bibliographical Handbooks, No. 1.) Paris, UNESCO; New York, Columbia University Press, 1953. 142 pp., diagrs. $1.75.

ELECTRONICS

Transistors Handbook. William Dealtry Bevitt. Englewood Cliffs, N.J., Prentice-Hall, Inc., 1956. 410 pp., diagrs. $9.00.

This handbook contains a survey of current information on transistors, their circuits, and their applications in modern industry. The first half of the book deals with fundamental concepts, the different types of transistors, their characteristics and their measurements, and the circuit properties and behavior of transistors. The last half of the work covers practical applications and circuits of transistors. The appendage includes both an author and subject index plus an appendix that contains a chart listing commercially available transistors together with their characteristics. The author is Transistor Applications Engineer, Commercial Engineering Department, CBS-Hytron.

Electronics in Industry. George M. Chute. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1956. 431 pp., illus., diagrs. $7.50.

A treatise that deals with the basic fundamentals of electronic devices; intended for those who use and service such equipment. The first edition appeared in 1946. The present revision substitutes recent designs of industrial controls, while those for resistance welding are covered more completely. A new chapter has been added on simple closed-loop systems which gives a background for feedback controls. Most chapters are followed by problems that have been used in class instruction by the author. Material is so arranged and supplemented that it may be used for a general or survey course by technical institutes or for university students of mechanical, chemical, civil, electrical, or aeronautical engineering. The author is Professor of Electrical Engineering, University of Detroit.

ASTM Standards on Metallic Electrical Conductors, Dec., 1955. Sponsored by ASTM Committee B-1 on Wires for Electrical Conductors. Philadelphia, American Society for Testing Materials, 1956. 298 pp., diagrs., tables. $3.50.

INSTRUMENTS

Symposium: The Vortex Tube as a True Free Air Thermometer; Held May 24, 1955, at Armour Research Foundation. Organized at the Request of the Air Research and Development Command, Wright Air Development Center. Chicago, Armour Research Foundation, Illinois Institute of Technology, 1955. 167 pp., illus., diagrs.

Contents: (1) Requirements for Vortex Thermometers, John C. Bellamy. (2) Thermal Phenomena in a Vortex, C. Desmond Pengelley. (3) Investigation of the Energy Distribution in a High Velocity Vortex Type Flow, E. R. G. Eckert and J. P. Hartnett. (4) Cornell Aeronautical Laboratory Vortex Free Air Thermometer, Jack Beneke. (5) The Vortex Tube as an Acoustic Generator with Application to True Airspeed Measurement, James P. Nicklas. (6) The Internal Characteristics and Probe Variables of the NRL Axial-Flow Vortex Thermometer, R. M. Schecter and R. E. Ruskin. (7) Operational Characteristics of the NRL Axial-Flow Vortex Thermometer, R. M. Schecter and R. E. Ruskin. (8) Performance of the ARF Vortex Free Air Thermometer at Subsonic and Supersonic Velocities, Jack C. Hedge. (9) NRL Vortex Thermometer Installation and Reliability Experience, C. A. Stiefelmaier.

Instrument Engineering, Volume 3, Applications of the Instrument Engineering Method, Part 1. Charles S. Draper, Walter McKay, and Sidney Lees. New York, McGraw-Hill Book Company, Inc., 1955. 879 pp., illus., figs., diagrs. $17.50.

This volume, intended for students and engineers interested in the theory and applications of measuring systems, is the third in a series devoted to the study of the concepts, theory, and methods of instrument engineering. The previous volumes have already been reviewed in the AERONAUTICAL ENGINEERING REVIEW—Volume 1 in the February, 1953, issue and Volume 2 in the September, 1954, issue.

Since Volume 3 is written with considerable repetition of the fundamentals of Volume 1 and the mathematical principles of Volume 2, it will be sufficient as a self-contained text and reference book on measuring instruments and systems. The necessary information is presented in the form of mathematical results plotted as nondimensional curve families. Methods for solving measurement problems are built up by means of typical examples, beginning with thermometers that have the simplest possible performance equations. Following are discussions on instruments and measuring systems of increasing complexity, including electromechanical measuring devices, pressure-measuring systems, integrators and differentiators, analog computers, and vibration-measuring equipment. The concepts, symbols, and methods developed in this pattern are equally effective for handling the theory of systems that include feedback loops. Applications of this type will make up the subject matter of Part 2 of Volume 3. Stress in preparation has been placed on the complete treatment of fundamentals, supplemented by numerical data in nondimensional plots. The text is highlighted by nearly 200 illustrations and 100 tables and charts and is documented with a 15-page bibliography. The authors are all with the Aeronautical Engineering Department, Massachusetts Institute of Technology; C. S. Draper as Head, W. McKay as Associate Professor, and S. Lees as Assistant Professor.

Random Processes in Automatic Control. J. Halcombe Laning, Jr., and Richard H. Battin. New York, McGraw-Hill Book Company, Inc., 1956. 434 pp., diagrs., tables. $10.

A book for the practical engineer and the theoretical research scientist. It provides a basic background in the theory of random signals and noise together with practical techniques to be used in the analysis and synthesis of linear control systems that are subjected to random inputs. The subject matter in the field has become so extensive that the authors have had to exclude information theory and its applications to radar, communications, and digital-data processing. The first half of the book deals with the basic concepts of probability and random time functions. Special emphasis is given to the nonstationary problems and the use of modern automatic computing equipment to provide feasible solutions to such problems. Detailed examples illustrate each new idea presented in the text. Most chapters contain a collection of problems of varying degrees of difficulty. The material in this text is the outgrowth of a set of lecture notes, first prepared in 1951, to meet the needs of a course on random processes in the field of automatic control given by the authors in the Aeronautical Engineering Department at Massachusetts Institute of Technology. Dr. Laning and Dr. Battin serve as Deputy Associate Director and Assistant Director, respectively, at the Instrumentation Laboratory of M.I.T.

Panel Discussion on Pyrometric Practices. Presented at the 58th Annual Meeting, ASTM, Atlantic City, N.J., June 30, 1955. (ASTM Special Technical Publication No. 178.) Philadelphia, American Society for Testing Materials, 1956. 41 pp., illus., diagrs. $1.50.

Contents: Thermocouple Immersion Errors, J. M. Berry and D. L. Martin. Summary of Pyrometric Procedure Employed by One Company in Creep-Rupture Testing and an Analysis of Results Obtained, W. E. Leyda. Creep and Rupture Test Pyrometry, Charles R. Wilks. General Discussion.

MACHINE ELEMENTS

Handbook of Fastening and Joining of Metal Parts. Vallory H. Laughner and Augustus D. Hargan. New York, McGraw-Hill Book Company, Inc., 1956. 622 pp., illus., diagrs., tables. $15.

The design engineer and the production engineer will find this handbook both a reference and an idea source dealing with all known methods of joining metal parts. The volume covers such methods of fastening and joining as screw threads and nuts, types of welding, collars, couplings, hinges, keys, brazing, and soldering. Detailed information is given on standards and suitability of various methods for similar and dissimilar metals. All types of resistance welding, gas welding, and arc welding are described. There are data for welded strengths in various ferrous and nonferrous alloys, plus advantages and disadvantages of kinds of joints. One section lists the types of resins and adhesives that can be used for fastening metal to metal and metal to other materials. A unique feature of the book is a 200-page section in picture-and-caption style that gives practical answers to special problems in fastening and joining metals.

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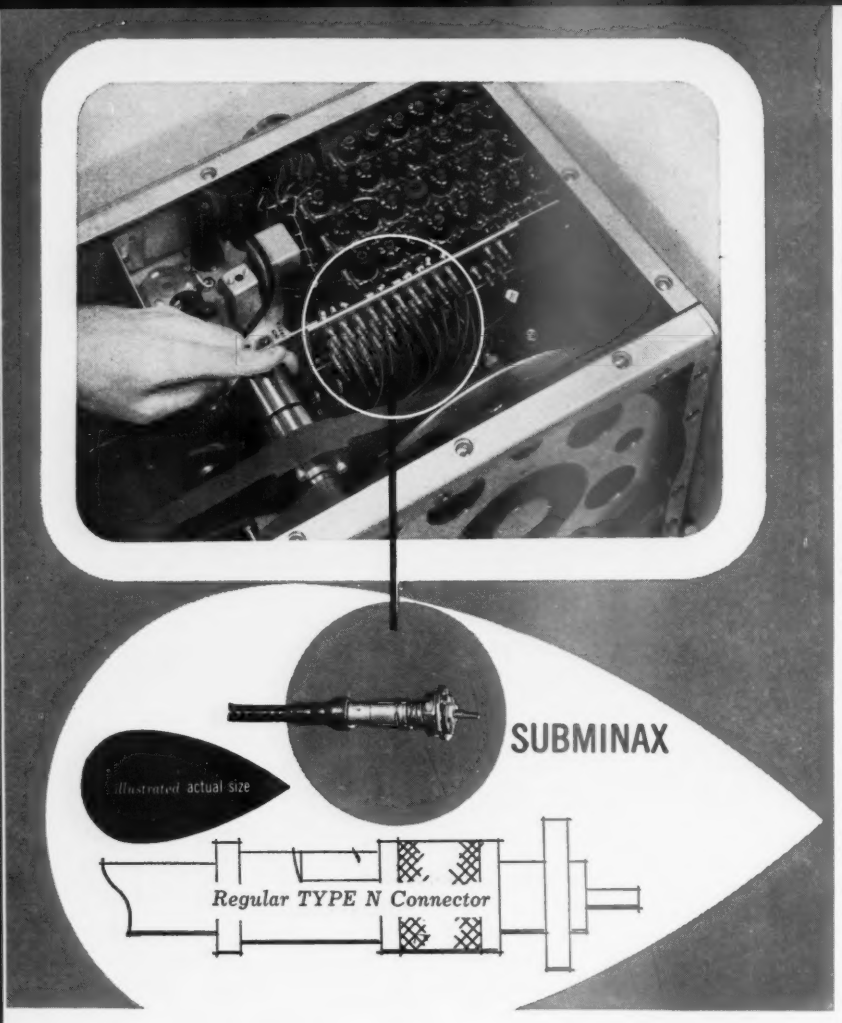

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Cams: Design, Dynamics, and Accuracy. Harold A. Rothbart. New York, John Wiley & Sons, Inc., 1956. 350 pp., illus., diagrs., tables. $9.50.

This work, written primarily for the machine designer, deals with kinematics, dynamics, and machine design, using cams as a basis. Both the theoretical and practical aspects of the subject are covered. On the practical side, concrete recommendations are made concerning such topics as mass, acceleration, materials, and the type of cam and follower to be used. The later chapters offer a discussion of profile accuracy and errors. Mathematical treatment is kept to a minimum, only that significant to design being presented. The author is a member of the Mechanical Engineering Department, City College of New York, and a consulting professional engineer.

MANPOWER

Soviet Professional Manpower, Its Education, Training, and Supply. National Academy of Sciences, National Research Council. Nicholas De Witt, Editor. Washington, National Science Foundation; Sold by Superintendent of Documents, 1955. 400 pp., diagrs., tables. $1.25.

This study is an investigation into the availability and growth of the specialized manpower resources of the U.S.S.R., based upon the Soviet educational effort during the past 25 years. Most of the research and the preparation of material was done at the Russian Research Center, Harvard University. Because of Soviet secretiveness, incomplete statistics, and recent developments in Soviet education, the study must be regarded as a preliminary approach. The subject matter is analyzed under the following chapter headings: (1) General setting of the Soviet educational system, (2) Soviet primary and secondary education, (3) Secondary semiprofessional training, (4) Higher education and professional training, (5) Research training programs and advanced degrees, and (6) Soviet professional and specialized manpower. Ten pages of bibliography and a detailed subject index conclude the book.

MATHEMATICS

Symposia in Applied Mathematics, Vol. 6, Numerical Analysis. Proceedings of the 6th Symposium in Applied Mathematics of the American Mathematical Society Held at the Santa Monica City College, August 26–28, 1953. Cosponsored by the National Bureau of Standards. John H Curtiss, Editor. New York, McGraw-Hill Book Company, Inc., 1956. 303 pp., diagrs., tables. $9.75.

Contents: Computational Problems in the Theory of Dynamic Programming, Richard Bellman. Some Methods for Solutions of Boundary-Value Problems of Linear Partial Differential Equations, Stefan Bergman. Computational Aspects of Certain Combinatorial Problems, R. H. Bruck. Numerical Results on the Shock Configuration in Mach Reflection, D. R. Clutterham and A. H. Taub. Some Applications of Gradient Methods, Joseph W. Fischbach. Some Qualitative Comments on Stability Considerations in Partial Difference Equations, S. P. Frankel. Approximations in Numerical Analysis—A Report on a Study, Cecil Hastings, Jr., Jeanne Hayward, and James P. Wong, Jr. The Conjugate-Gradient Method for Solving Linear Systems, Magnus R. Hestenes. Number Theory on the SWAC, Emma Lehmer. The Assignment Problem. T. S. Motzkin. The Method of Steepest Descent, P. C. Rosenbloom. Function Spaces and Approximation, Arthur Sard. Some Computational Problems in Algebraic Number Theory, Olga Taussky. Machine Attacks on Problems Whose Variables are Permutations, C. B. Tompkins. Best-Approximation Polynomials of Given Degree, J. L. Walsh. Recent Results in Numerical Methods of Conformal Mapping, S. E. Warschawski. On the Asymptotic Transformation of Certain Distributions into the Normal Distribution, Wolfgang Wasow.

Error Bounds for Eigenvalues of Symmetric Integral Equations, Helmut Wielandt. On the Solution of Linear Systems by Iteration, David Young.

Symposium on Monte Carlo Methods. Held at the University of Florida, March 16–17, 1954; Conducted by the Statistical Laboratory. Sponsored by Wright Air Development Center of the Air Research and Development Command. Edited by Herbert A. Meyer. New York, John Wiley & Sons, Inc., 1956. 382 pp., diagrs. $7.50.

Contents: An Introductory Note, A. W. Marshall. Generation of Pseudo Random Numbers, Olga Taussky and John Todd. Phase Shifts—Middle Squares—Wave Equation, N. Metropolis. A General Theory of Stochastic Estimates of the Neumann Series for the Solution of Certain Fredholm Integral Equations, G. E. Albert. Neighbor Sets for Random Walks and Difference Equations, Theodore S. Motzkin. Monte Carlo Computations, Nancy M. Dismuke. Applications of Monte Carlo Methods to Tactical Games, S. Ulam. Conditional Monte Carlo for Normal Samples, Hale F. Trotter and John W. Tukey. Monte Carlo Techniques in a Complex Problem about Normal Samples, Harvey J. Arnold, Bradley D. Bucher, Hale F. Trotter, and John W. Tukey. An Application of the Monte Carlo Method to a Problem in Gamma Ray Diffusion, Martin J. Berger. Stochastic Calculations of Gamma Ray Diffusion, L. A. Beach and R. B. Theus. Application of Multiple Stage Sampling Procedures to Monte Carlo Problems, A. W. Marshall. Questionable Usefulness of Variance for Measuring Estimate Accuracy in Monte Carlo Importance Sampling Problems, John E. Walsh. Experimental Determination of Eigenvalues and Dynamic Influence Coefficients for Complex Structures such as Airplanes, C. W. Vickery. Use of Different Monte Carlo Sampling Techniques, Herman Kahn. A Theoretical Comparison of the Efficiencies of Two Classical Methods and a Monte Carlo Method for Computing One Component of the Solution of a Set of Linear Algebraic Equations, J. H. Curtiss. A Description of the Generation and Testing of a Set of Random Normal Deviates, E. J. Lytle, Jr. Machine Sampling from Given Probability Distributions, James W. Butler. A Monte Carlo Technique for Obtaining Tests and Confidence Intervals for Insurance Mortality Rates, John E. Walsh. Experiments and Models for the Monte Carlo Method, Alwin Walther. Bibliography (87 pages). Name, Source, and Subject Indexes.

Principles and Techniques of Applied Mathematics. Bernard Friedman. New York, John Wiley & Sons, Inc., 1956. 315 pp. $8.00.

The subject matter of this book has been presented for several years as a 1-year course in the Graduate School of New York University. The prerequisites of the course are a knowledge of linear algebra and complex integration. The author's approach is that the study of abstract systems can help in the solution of concrete problems. There are two themes developed: (1) the demonstration of how the abstract theory of linear operators can be used to unify and systematize the techniques of applied mathematics, and (2) the explanation of specific techniques which can be used to obtain explicit solutions of partial differential equations.

Contents: Linear Spaces. Spectral Theory of Operators. Green's Functions. Eigenvalue Problems of Ordinary Differential Equations. Partial Differential Equations. Bibliography. Index.

Asymptotic Expansions. A. Erdélyi. New York, Dover Publications, Inc., 1956. 108 pp. $1.35.

This is a reprint of a technical report prepared under contract for the Office of Naval Research. It is an introduction to various methods for the asymptotical evaluation of integrals containing a large parameter and to the study of solutions of ordinary linear differential equations by means of asymptotical expansions. The author is Professor of Mathematics, California Institute of Technology.

Infinite Sequences and Series. Konrad Knopp. Translated by Frederick Bagemihl. New York, Dover Publications, Inc., 1956. 186 pp. $1.75.

The first appearance of a new work by Dr. Knopp, Emeritus Professor of Mathematics at the University of Tübingen. Concentrated upon two topics of modern mathematics, it presents the theory of infinite sequences and series. It is an introductory presentation, designed to give the student sufficient background to penetrate into more advanced topics by himself.

Abacs or Nomograms; An Introduction to Their Theory and Construction, Illustrated by Examples from Engineering and Physics. A Giet. Translated and revised by J. W. Head and H. D. Phippen. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1956. 225 pp., diagrs., tables. $12.

This edition has been adapted from the French for English readers. It will be of practical interest to engineers and physicists and to others who require time-saving methods when performing repetitive and complicated calculations. Essentially practical, the text not only demonstrates the many and varied applications of the abac or nomogram but also shows how charts may be constructed even without highly specialized mathematical knowledge. Both Cartesian abacs and alignment charts are discussed, and many examples are drawn from the fields of mechanics, physics, and electrical engineering.

An Essay on the Foundations of Geometry. Bertrand A. W. Russell. (Reprint of the 1897 Ed.) New York, Dover Publications, Inc., 1956. 201 pp. $1.50.

Integral Transforms in Mathematical Physics. C. J. Tranter. 2nd Ed. London, Methuen & Co., Ltd.; New York, John Wiley & Sons, Inc., 1956. 133 pp. $2.00. The present edition contains an additional chapter relating recent work on dual integral equations.

MECHANICS

Engineering Mechanics. S. Timoshenko and D. H. Young. 4th Ed. New York, McGraw-Hill Book Company, Inc., 1956. 478 pp., diagrs. $7.50.

A basic training course in engineering mechanics for the undergraduate. Essential changes from the third edition of 1951 are simplification of the text and de-emphasis of the algebraic treatment of problems.

METALS AND ALLOYS

Symposium on Metallic Materials for Service at Temperatures Above 1600°F. Presented at the 58th Annual Meeting, ASTM, Atlantic City, N.J., June 30, 1955. (ASTM Special Technical Publication No. 174.) Philadelphia, American Society for Testing Materials, 1956. 193 pp., illus., diagrs., tables. $3.50.

Contents: Some Sheet and Bucket Materials for Jet-Engine Application at 1600°F and Higher, J. P. Denny, L. P. Jahnke, E. S. Jones, and F. C. Robertshaw, Jr. Influence of Boron on Cast Cobalt-Base S-816 Alloy, W. E. Blatz, E. E. Reynolds, and W. W. Dyrkacz. Effect of Heat Treatment and Structure Upon Creep Properties of Nimonic Alloys Between 750 and 950°C, W. Betteridge and R. A. Smith. Stress-Rupture Properties of Inconel 700 and Correlation on the Basis of Several Time-Temperature Parameters, S. S. Manson and G. Succop. Chromium-Nickel Alloys for High-Temperature Applications, Albert G. Bucklin and Nicholas J. Grant. Effect of Rare Earth Additions on the High-Temperature Properties of a Cobalt-Base Alloy, J. E. Breen and J. R. Lane. Creep, Rupture, and Notch Sensitivity Properties of S-816 Alloy Up to 1650°F Under Fatigue and Static Stress, F. Vitovec and B. J. Lazan. Titanium-Carbide Products Produced by the Infiltration Technique, Leonard P. Skolnick and Claus G. Goetzel. High-Temperature Properties of Molybdenum-Rich Alloy Compositions Made by Powder Metallurgy Methods, W. L. Bruckart and R. I. Jaffee. Tension and Torsion Tests on Nimonic Alloys at High Temperatures, E. D. Ward and W. G. Tallis. Thermal Fatigue Testing of Sheet Metal, H. E. Lardge. Thermal Shock Testing of High-Temperature Metallic Materials, Thomas A. Hunter. The Development of Zirconium-Rich Protective Coatings and Brazing Materials for Heat Resisting Alloys, A. Blainey.

Metallurgical Thermochemistry. O. Kubaschewski and E. Ll. Evans. 2nd Rev. Ed. London, Pergamon Press, Ltd; New York, John Wiley & Sons, Inc., 1956. 410 pp., diagrs., tables. $10.

An introductory and reference work first published in 1951. The present, somewhat enlarged, edition contains the following changes: The extensive tables of thermochemical data of metal compounds have been brought entirely up to date; incorporated with the text are critical assessments of data by the National Bureau of Standards, by L. Brewer of California University and by F. D. Richardson of the Nuffield Research Group for Extraction Metallurgy; two new sections, on nonregular solutions and slag-metal equilibria, have been added. The appendixes include an 11 page bibliography, a subject index, and a name index. O. Kubaschewski is Principal Scientific Officer at the National Physical Laboratory, and E. Ll. Evans is Senior Scientific Officer at the Chemical Research Laboratory.

Chromium; Vol. 1, Chemistry of Chromium and Its Compounds. Marvin J. Udy. (American Chemical Society Monograph No. 132.) New York, Reinhold Publishing Corporation, 1956. 433 pp., illus., diagrs., tables. $11.

Contents: (1) History of Chromium, Marvin J. Udy. (2) Mineralogy and Geology of Chromium, Thomas P. Thayer. (3) The Analytical Chemistry of Chromium, Earl J. Serfass and Raffaele F. Muraca. (4) Relation of Chromium to Health, Anna M. Baetjer. (5) Chromium In Soils, Plants, and Animals, George K. Davis. (6) The Physical and Chemical Properties of Compounds of Chromium, Murray C. Udy. (7) Chromium Chemicals: Their Industrial Use, Marc Darrin. (8) Production of Chromium Chemicals, Raymond L. Copson. (9) Chromium Chemicals in the Textile Industry, Charles L. Howarth. (10) Chromium Chemicals in the Tanning Industry, Robert M. Lollar. (11) Chromium Chemicals in Wood Preservation, H. W. Angell and W. H. Hartford. (12) Chromium Chemicals in Corrosion Prevention. (13) The Manufacture and Properties of Chromium Pigments, V. H. Chalupski. (14) Chromium Chemicals in the Graphic Arts, George W. Jorgensen and Michael H. Bruno. (15) Chromium Chemicals in the Oil and Gas Industries, Marc Darrin.

Symposium on Atmospheric Corrosion of Non-Ferrous Metals. Presented at the 58th Annual Meeting, ASTM, Atlantic City, N.J., June 29, 1955. (ASTM Special Publication No. 175.) Philadelphia, American Society for Testing Materials, 1956. 158 pp., illus., diagrs., tables. $2.75.

Contents: Report of Subcommittee VI on Atmospheric Corrosion. Resistance of Aluminum-Base Alloys to 20-Year Atmospheric Exposure, C. J. Walton and William King. Effect of 20-Year Marine Atmosphere Exposure on Some Aluminum Alloys, Fred M. Reinhart and George A. Ellinger. Effect of Natural Atmospheres on Copper Alloys: 20-Year Test, A. W. Tracy. The Atmospheric Corrosion of Copper—Results of 20-Year Tests, D. H. Thompson, A. W. Tracy, and John R. Freeman, Jr. Atmospheric Galvanic Corrosion of Magnesium Coupled to Other Metals, H. O. Teeple. Galvanic Couple Corrosion Studies by Means of the Threaded Bolt and Wire Test, K. G. Compton and A. Mendizza. The Atmospheric Corrosion of Rolled Zinc, E. A. Anderson. The Use of Lead and Tin Outdoors, George O. Hiers and Elbert J. Minarcik. Atmospheric Corrosion Behavior of Some Nickel Alloys, H. R. Copson.

ASTM Standards on Copper and Copper Alloys, 1955; Copper and Copper Alloys, Cast

and Wrought Copper and Copper-Alloy Electrical Conductors Non-Ferrous Metals Used in Copper Alloys. Sponsored by ASTM Committee B-5 on Copper and Copper Alloys, Cast and Wrought. Philadelphia, American Society for Testing Materials, 1956. 642 pp., illus., diagrs., tables. $5.75.

METEOROLOGY

Weather Analysis and Forecasting. Vol. 1, Motion and Motion Systems; Vol. 2, Weather and Weather Systems. Sverre Petterssen. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1956. Vol. 1, 428 pp.; Vol. 2, 266 pp., diagrs., tables. Vol. 1, $8.50; Vol. 2, $6.00.

These two volumes constitute a general and thorough text on forecasting which aims at minimizing the difference between synoptic and dynamic meteorology. The text, which first appeared in 1940, will be of value to professional meteorologists as well as to university students. The author is Professor, Department of Meteorology, University of Chicago. Volume 1 emphasizes the dynamics of atmospheric processes. In it are treated the dynamics of motion systems—cyclones, anticyclones, fronts, and upper waves. The basic equations of hydrodynamics take the reader, through various analyses, to techniques for forecasting the development and movement of pressure systems at all levels. A number of special forecasting procedures illustrated by numerous examples are discussed. Volume 2 deals with weather. The emphasis is on the thermodynamics of atmospheric processes. The book begins with a treatment of the exchange processes and develops the theory of air masses and thermodynamic processes. Then condensation and precipitation, convective clouds, showers, thunderstorms, squall lines, and tornadoes are discussed. Subsequent chapters deal with fog, migratory cloud and weather systems, and various dynamic and statistical techniques for predicting clouds and weather.

MILITARY AVIATION

Royal New Zealand Air Force; Official History of New Zealand in the Second World War 1939–45. J. M. S. Ross. Wellington, New Zealand, War History Branch, Dept. of Internal Affairs; Distributed by Whitcombe & Tombs Ltd., Christchurch, New Zealand, 1955. 343 pp., illus., colored maps. A concluding chapter outlines briefly the postwar development of the Air Force up to the end of 1954.

NUCLEAR ENERGY

Reactor Shielding Design Manual. Edited by Theodore Rockwell, III. Princeton, N.J., D. Van Nostrand Company, Inc., 1956. 472 pp., illus., diagrs., tables. $6.00.

The purpose of this manual is to help the engineer or scientist to design a practical shield by making available the techniques and data developed by the Naval Reactors Program and Pressurized Water Reactor Program of the Atomic Energy Commission. The methods discussed have two salient features: (1) They have been actually used for, and tested on, real power reactor shields, and (2) they form a basic approach rather than a mock-up approach and thus permit design of shields without expensive and time-consuming use of the reactor facilities in which full-scale shielding mock-ups can be made. The design methods described include detailed illustrations of the use of general formulas in actual shield design, as well as brief derivations of many of them. The section on materials deals with the basic components of shields such as concrete, iron, stainless steel, lead, polyethylene, and various borated compounds. There are tabulations and figures on flux to dose conversion, build-up factors, gamma rays resulting from neutron capture, and various formulas for different shield geometries. Additional features include a discussion based on actual experience of placement of coolant machinery and structure inside the secondary shield and hints and graphs for determining source points in a numerical procedure for finding attenuation through shields. The editor is Technical Director, Naval Reactors Branch Division of Reactor Development, U.S. Atomic Energy Commission.

Reactor Handbook: Physics. U.S. Atomic Energy Commission. New York, McGraw-Hill Book Company, Inc., 1955. 790 pp., diagrs., tables. $12.

This volume deals with reactor physics and radiation shielding and is issued for convenient reference use by scientists and engineers engaged on AEC reactor projects. Section 1 discusses theoretical and experimental techniques used in designing and evaluating various experimental and research reactors. Experimental and calculated solutions for various shielding problems and methods of tailoring these solutions to new problems are developed in Section 2. It should be pointed out that the publication of the Handbook was handicapped by a time limitation. The result is recognized by the Review Board of the Reactor Development Division of the AEC as a compromise of what is most desirable in a handbook and what is practical under the present circumstances. The ultimate success of the Handbook will depend a great deal upon the refinements in subject matter and presentation which will come about in subsequent revisions.

Contents: *Section 1:* Reactor Physics. Experimental Methods. Nuclear Physics. Kinetic Theory of Neutrons. Reactor Statics; Theory and General Results. Reactor Statics; Experimental and Numerical Results. Reactor Dynamics. *Section 2:* Radiation Shielding. Sources of Radiation. Permissible Levels of Radiation. Gamma-Ray Attenuation. Neutron Attenuation. Geometry. Ducts Through Shields. Heat Generation in Shields. Shield Optimization with Respect to Weight. Shield Materials.

Research Reactors. U.S. Atomic Energy Commission. New York, McGraw-Hill Book Company, Inc., 1955. 442 pp., illus., diagrs., tables. $6.50.

Detailed descriptions of six representative types of U.S. research reactors are given in this book. For each of the various types, the book deals with general design features, core design and fuel handling, cooling system (where applicable), control and instrumentation, shielding, experimental facilities, and operating characteristics. Selected design drawings are included. The six reactors discussed include three types of light-water-moderated reactors (solution type, pool type, and materials-testing reactor), one hydrocarbon-moderated, one heavy-water-moderated, and one graphite-moderated reactor. This selection is in line with the trend to all-purpose designs that furnish a maximum neutron flux and maximum experimental versatility for a given budget.

PILOTING

Airline Transport Pilot Rating. Charles A. Zweng and Allan C. Zweng. 8th Rev. Ed. North Hollywood, Calif., Pan American Navigation Service, June, 1956. 354 pp., illus., diagrs. $5.50.

Contents: The Airline Pilot. Instruments. Instrument Flying. Flying the Omnirange. ILS and Radar. Dead Reckoning. Charts and Chart Reading. Radio Communications and Navigation Aids. Radio Navigation. Meteorology. Weather Maps and Reports. Weight and Balance. Turbo-Jet, Turbo-Prop, and Compound Engines. Air Traffic Control. Civil Air Regulations. Typical Multiple-Choice Examinations. Index.

POWER PLANTS

Aircraft Engines of the World, 1956. Paul H. Wilkinson. New York, Paul H. Wilkinson, 1956. 320 pp., illus., diagrs., tables. $15.

The latest edition of this annual contains data on more than 30 new engines, including 23 main jet engines and numerous auxiliary gas turbines. Completely revised tabulations present 53 turbojets, 22 turbojets with afterburners, and 17 turboprops. Activities of the manufacturers and recent air-liner information are included in the introduction. The Accessories and Equipment section describes and illustrates many of the latest products of the United States and Great Britain. The Aircraft and Their Engines section contains seven tabulations of more than 300 military aircraft, commercial aircraft, and cargo-transports, and their engines.

PRODUCTION

Resistance Welding, Theory and Use. Prepared by Resistance Welding Committee, American Welding Society. New York, Reinhold Publishing Corp., 1956. 163 pp., illus., diagrs. $4.50.

A handbook on the basic principles of resistance welding. All resistance welding processes are covered, including the newest developments such as slope control and aluminum welding. There are descriptions of the different types of resistance welding machines, electrodes, and controls used, and finally there are discussions on the weldability of different metals and how quality control and inspection tests and methods are applied to obtain consistently good welds.

ROCKET SLEDS

Second Experimental Track Symposium: Seminar Reports and Abstracts of Papers, held at Holywood, Calif., and the Air Force Flight Test Center, Edwards Air Force Base, Calif., September 26–28, 1955. Edwards AFB, Calif., U.S. Air Force Flight Test Center, ARDC, 1955. 55 pp.

Contents: *Seminars:* (1) The Role of Liquid Propellants in High Speed Track Testing. (2) Instrumentation for Experimental Tracks. (3) Parachute Development Testing. (4) Escape Systems Testing. (5) Track Testing Development Problems. (6) Future Requirements for Track Testing Support.

Abstracts of Papers: Status Report on SNORT, W. D. Drinkwater. Use of Rocket Sleds in Experimental Wind Blast Tests, J. P. Stapp. The Use of Shock Isolation Systems, Ernest Coleal. Activity Report on AFFTC Tracks, R. L. King. Introduction to Project SMART, C. A. Brosterhous. Development of a Water Brake Recovery System, C. T. Hurd. The SNORT System for Measuring Sled Position and Time, B. W. Pike. Aberdeen Proving Ground Ballistic Track, M. E. Bonnett. The Dynamics of Crash Restraint Harnesses, Y. Hiroshige. Parachute Testing on the High Speed Track, R. Berndt. Armament Testing on High Speed Tracks, B. R. Egbert. The Flow Characteristics of a Ram Inlet and Wind Tunnel Combination, G. Eber.

SAFETY

Aircraft Fueling. New York, Flight Safety Foundation, 1956. 42 pp., diagrs.

A booklet devoted chiefly to the explanation of why certain precautions and methods are necessary in the handling of fuel for aircraft.

SPACE TRAVEL

Earth Satellites as Research Vehicles. Proceedings of Symposium Held April 18, 1956, Philadelphia. (Journal of the Franklin Institute Monograph No. 2.) Philadelphia, June, 1956. 115 pp., diagrs., illus., tables. $2.50.

The underlying theme of this symposium is the peaceful development of rocketry and the scientific utility of satellite vehicles in space research. The IGY Earth Satellite Program is described fully, including details on the radio and optical tracking systems now being organized to monitor the Vanguard satellites soon to be launched. The problem of recovery of physical data from such vehicles in the future is discussed with reference to such items as photographic film, specimens of meteoric matter, biological specimens, and the like. An artificial satellite time and radio orbit is proposed, and the selection of polar orbits versus equatorial orbits is debated in a paper devoted to celestial navigation techniques. The major problem areas in astronauti-

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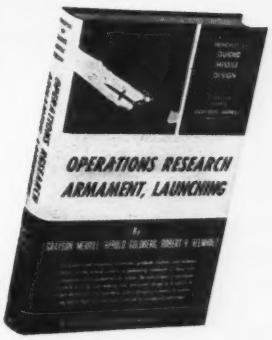

by Grayson Merrill, Captain, USN; Harold Goldberg, Vice-President for Research, Emerson Radio-phonograph Corporation; Robert H. Helmholz, U. S. Naval Air Missile Test Center

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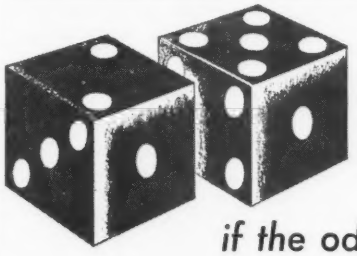

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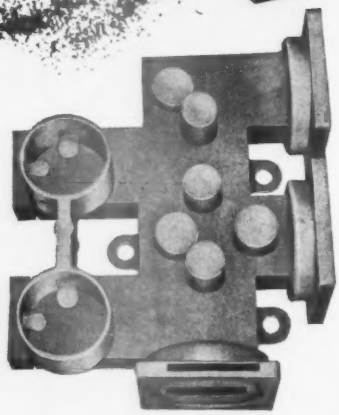

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cal and space medical research are defined and discussed by the several contributors to this symposium. The implications for astrophysical research and the specific problems of satellite motion are presented, and the feasibility of a moon rocket is re-examined in the light of present day capability and the necessary performance requirements for such a voyage.

Contents: The International Geophysical Year Earth Satellite Program, Homer E. Newell, Jr. The Moon Rocket, George H. Clement. Astronautical and Space-Medical Research with Automatic Satellites, Krafft A. Ehricke. Astrophysical Research with an Artificial Satellite, Lyman Spitzer, Jr. The Effect of the Earth's Oblateness and Atmosphere on a Satellite Orbit, John De Nike. "Astro"—an Artificial Celestial Navigation System, Lovell Lawrence, Jr. Recovery of Data in Physical Form, R. W. Porter.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis, Vol. 13, No. 2. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., Society for Experimental Stress Analysis, 1956. 197 pp., illus., diagrs., tables. $6.00.

Contents: Solution of Torsional Problems with the Aid of the Electrical Conducting Sheet Analogy, N. E. Friedmann, Y. Yamamoto, and D. Rosenthal. Photoelastic Investigation of Stresses in Conical Head Pressure Vessels, L. W. Smith and C. K. Cooper. The Interference Screen Method for Isopachic Patterns (Moiré Method), G. Mesmer. Field Testing of Diesel Locomotive Axles, R. A. Moreau and L. Petersen. Simulated Service Testing, L. F. Kooistra. Structural Testing of Aircraft Propellers, D. G. Richards. Metal Cutting Measurements and their Interpretation, E. G. Loewen and N. H. Cook. Dilation Measurements of Steel Sphere and Rock Deformations at Kemano, B.C., G. A. Brewer. Methods of Waterproofing SR-4 Strain Gages, P. M. Palermo. The Curvilinear Rosette Method as an Auxiliary Device for the Numerical Solution of Laplace's Equation, P. S. Theocaris. Application of a New Deformeter to Two-Dimensional Thermal Stress Problems, J. B. Barriage and A. J. Durelli. Three Dimensional Photoelastic Analysis of Shafts in Pure Torsion and a Comparison with Results from Relaxation, R. C. Johnson. Photoelastic Evaluation of Individual Principal Stresses by Large Field Absolute Retardation Measurements, D. Post. Model Analysis of Three-Dimensional Slab Structures, K. H. Gerstle and R. W. Clough. A Simple Extension of Southwell's Method for Determining the Elastic General Instability Pressure of Ring-Stiffened Cylinders Subject to External Hydrostatic Pressure, G. D. Galletly and T. E. Reynolds. A Comparison of the Stresses in Deep Arches with Solid and Hollow Spandrels, S. R. Sparkes and E. H. Brown. Stresses in Projectiles During Penetration, J. I. Bluhm. The Mechanical Properties of Certain Steels Indicated by Axial Dynamic Load Tests, R. C. Smith, T. E. Pardue, and I. Vigness.

Bibliographie der Veröffentlichungen über den Leichtbau und seine Randgebiete im deutschen und ausländischen Schrifttum aus den Jahren 1940 bis 1954 (Bibliography of Publications on Light Weight Construction and Related Fields in German and Foreign Literature from 1940 to 1954). H. Winter. Berlin, Springer-Verlag, 1955. 1,003 pp., illus. $18.80.

Reducing the weight of a design is purely an economical consideration. Some of the results are a saving in energy required and in transport costs, economy in materials, and an increase in the frequency of transport—i.e., the economy and capacity of transport. Since several branches of engineering derive benefit from the saving of weight, this first incomplete compilation is an attempt to fill the gap in the field brought about by World War II and the cessation of German aircraft construction since 1945. It is expected that supplements and addenda will be issued later on.

Starting with 1930, the list includes publications on the subject issued since then. Publica-

tions are predominantly those from the United States, Britain, France, and Germany. The bibliography is divided into two sections—books, and papers and articles published in periodicals. Some of the 85 subject divisions in the book section include statics of plates and shells, dynamics (vibrations), strength of materials and other properties, iron materials, plastics, rubber, adhesives, welding, and riveting. Some of the 360 subject divisions covered in the periodicals section include plane structures, statics of plates, shells, vibrations of structures, strength of materials and other properties, heat treatment, coatings on metals, fatigue, loading, metals, ceramics, and construction. Both sections are preceded by a classification scheme with equivalent terms in English and German. Within the classified sections, the individual publications are arranged chronologically according to year of publication. Introductory descriptive text is in both English and German. The subject index is in German.

THERMODYNAMICS

Thermodynamics and Physics of Matter. Frederick D. Rossini, Editor. (High Speed Aerodynamics and Jet Propulsion Series, Vol. 1.) Princeton, N.J., Princeton University Press, 1955. 812 pp., diagrs., tables. $15.

The purpose of this volume is to provide information on the thermodynamic and physical properties of matter and their influence upon the related problems inherent in high-speed aerodynamics and jet propulsion. Many phases of the study of solids, liquids, and gases are covered by the several contributors, and much fundamental data concerning the behavior of matter is included in the text. At the conclusion of each section there is a bibliography of pertinent books and papers.

Contents: Section A, Fundamentals of Thermodynamics, Frederick D. Rossini. Section B, Fundamental Physics of Gases, Karl F. Herzfeld, Virginia Griffing, Joseph O. Hirschfelder, C. F. Curtiss, R. B. Bird, and Ellen Spotz. Section C, Thermodynamic Properties of Real Gases and Mixtures of Real Gases, James A. Beattie. Section D, The Transport Properties of Gases and Gaseous Mixtures, Joseph O. Hirschfelder, C. F. Curtiss, R. B. Bird, and Ellen L. Spotz. Section E, Critical Phenomena, O. K. Rice. Section F, Properties of Liquids and Liquid Solutions, John M. Richardson and Stuart R. Brinkley, Jr. Section G, Properties of Solids and Solid Solutions, P. P. Ewald. Section H, Relaxation Phenomena in Gases, Karl F. Herzfeld. Section I, Gases at Low Densities, Immanuel Estermann. Section J, The Thermodynamics of Irreversible Processes, C. F. Curtiss.

VIBRATION

Practical Solution of Torsional Vibration Problems; Vol. 1, Frequency Calculations. W. Ker Wilson. 3rd Rev. Ed. New York, John Wiley & Sons, Inc., 1956. 704 pp., illus., diagrs., tables. $16.

Completely rewritten, this edition of a work last revised in 1940 retains the original objective of providing an adequately comprehensive treatment in convenient reference form. The complete work remains in two volumes, but the text has been rearranged so that each volume now deals with a particular aspect of the subject. Volume 1 contains considerable additions, particularly in the sections dealing with geared systems and systems containing distributed masses. The effective inertia method for determining natural frequencies is discussed in greater detail, and there is a more comprehensive treatment of the application of this method in cases of coupled vibration. The introduction contains a survey of the history of the subject.

WIND TUNNELS

Seminar on Wind-Tunnel Techniques and Aerodynamics; Royal Institute of Technology, Stockholm, May 10–11, 1954. Stockholm, Division of Aeronautics, Royal Institute of Technology, 1955. 263 pp., illus., diagrs.

Contents: Brief Account of Swedish Wind Tunnels and Related Activity, S. Luthander. The Design of Large High-Speed Wind Tunnels, J. F. Parsons. Some Aerodynamic Techniques at the Royal Aircraft Establishment, L. F. Nicholson. Some Special Swedish Wind Tunnels; The SAAB 0.5 m^2 Jet Engine-Powered M = 0.5–1.5 Wind Tunnel, A. Anderberg. The Flygmotor 0.5 × 0.5 m^2, 9 ata, M = 0.7–3.6 Blow-Down Wind Tunnel, C.-E. Larsson. The Bofors Co. Aerodynamic Research Laboratory, C. Nelander. Factors Influencing Precision in Supersonic Wind Tunnels, R. Smelt. Development of Supersonic Wind Tunnel Facilities in Canada, J. Lukasiewicz. Presentation of the FFA 1 sq.m. Supersonic Wind Tunnel with Vacuum Rock Chamber, B. Reistad. Aeroballistic Research at the U.S. Naval Ordnance Laboratory, H. H. Kurzweg. Design Principles for Strain Gauge Balances, G. Gustafsson. Two Half-Model Balances, K. Fristedt. Starting Loads in Supersonic Wind Tunnels, Some Experiences, S. F. Erdmann. Some Applications of the Free-Oscillation Techniques for Measuring Stability Derivatives, K. Orlik-Rückemann. An Electronic Apparatus for Automatic Recording of the Logarithmic Decrement and Frequency of Oscillations, C. O. Olsson. Wind Tunnel Testing of Oscillating Models, J. B. Bratt. Test Techniques and Some Results about the Vortex Flow on Delta Wings, T. Ornberg. A Note on Supersonic and Transonic Flow around Delta Wings, P. O. Larsson. Visualization of Flow over Swept-Back Wings at Low Speeds, N. C. Lambourne. Methods for Investigation of Air Intakes, E. Bergstrom. Determination of Form Drag and Additive Drag in Supersonic Air Intakes from the Shock Wave Shape, L. Ohman. Aeronautical Research and Development in Sweden; Financial Background and Organization, H.-E. Lofkvist. A Note on the Flow Around Delta Wings, Torsten Ornberg (KTH-AERO Technical Note TN38).

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nozzle permitting a continuous variation of Mach Number.

Experiments with Slotted and Perforated Walls in a Two-Dimensional High-Speed Tunnel. D. W. Holder, R. J. North, and A. Chinneck. *Gt. Brit., ARC R&M 2955* (Nov., 1951), 1956. 59 pp. 12 refs. BIS, New York, $3.06.

Developing a Rational Procedure for Control System Design in a Gas Flow Process. G. V. Schwent, W. K. McGregor, and D. W. Russell. *ISA J.*, July, 1956, pp. 219–223. Analysis of gas-flow problems and the establishment of a procedure to design an automatic closed-loop control system for the primary external variables of a jet-engine testing facility.

Calibration of the Flexible Plate Nozzle in the Transonic Model Tunnel of the Propulsion Wind Tunnel. John C. Marchall. *USAF AEDC TN 56–5*, June, 1956. 36 pp. Discussion of the tunnel calibration for measuring the flow quality in the nozzle, with emphasis on the Mach Number distribution along the axial centerline of the nozzle. Pressure measurements are made at 16 points along the centerline, and local Mach Number is computed from local static pressure and the stilling chamber total pressure.

A Design of Electrical Control Heaters for Operation with a Supersonic, Blow-Down Wind Tunnel. Raymond A. Fetter, Jr. *U. Tex. DRL Rep. 382 (AFSOR TN-188)*, June, 1956. 76 pp. 17 refs. Development of a 420-kw. electrical resistance heater to maintain a constant air stagnation temperature in supersonic wind tunnels. The heating unit consists of a stainless-steel Inconel box containing filaments of Nichrome V wire held in place by ceramic beads. Three such units are arranged end to end in heavy pipe casing.

The Application of the Shock Tube to the Study of the Problems of Hypersonic Flight. A. Hertzberg. *Jet Propulsion*, July, 1956, pp. 549–554, 568. 18 refs. Description of the shock tube capable of generating the high-temperature conditions in air encountered in hypersonic flight, with a presentation of design modifications studied at CAL.

Apparatus and Techniques for the Application of a Water Flow System to the Study of Aerodynamic Systems. E. F. Winter and J. H. Deterding. *Brit. J. Appl. Phys.*, July, 1956, pp. 247–261.

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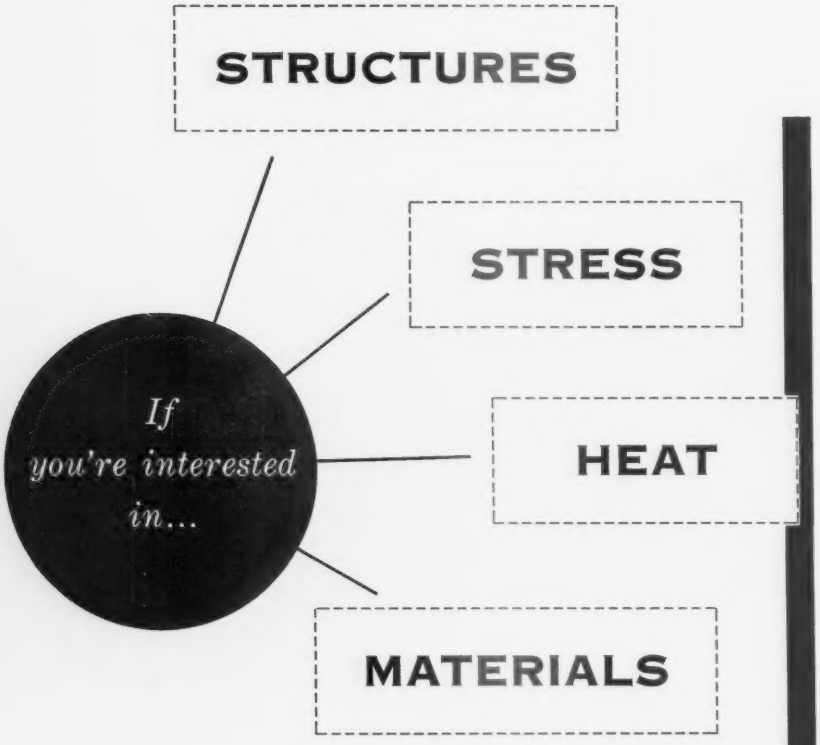

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ENGINEERS
For the analysis and design of missile structures and other airborne equipment. Also adhesives engineers, metallurgical and materials engineers with aircraft or missile design experience.

MECHANICAL ENGINEERS
To participate in the design and development of missiles, missile launchers, aircraft structure, component installation, environmental test equipment and general mechanical design.

AERONAUTICAL ENGINEERS
For the analysis and design of missile launching equipment for high-speed aircraft, including coordination and liaison with many major airframe manufacturers.

DYNAMICS ENGINEERS
To work on shock and vibration problems in an aerothermal environment. Also elasticians to work on advanced aerothermoelastic problems associated with high-speed flight.

ENGINEER
For research related to the selection of materials and development of fabrication techniques.

LIAISON ENGINEER
To work between Development Laboratories in Culver City and Engineering Laboratory in Tucson or between the Laboratory and subcontractors.

THERMODYNAMICIST
To perform analytical and experimental analysis of heat transfer from electronic components via natural convection, forced-air convection, and radiation.

These positions also available in the Research and Development activity at Tucson, Arizona.